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(PROFESSIONAL PAPER.)

ROCKY MOUNTAIN MINE TIMBERS.[1]

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STRENGTH.

OBJECT OF THE TESTS.

Approximately one-fourth of the timber cut in Colorado during 1911 was consumed by the mining industries of that State. A number of different species are used, and their relative strength is of considerable importance both to miners and producers of mine timbers. Native Douglas fir, the so-called "red spruce" of the Rocky Mountain region, has been the wood most suitable for use in mines, but it is no longer available for a very large part of the supply. The forests of lodgepole pine and Engelmann spruce, containing also several minor species, must furnish the bulk of the material. The Forest Service, in cooperation with the University of Colorado, has tested these different timbers to determine their relative strength.

Since the timbers are used both green and air-dried, the influence of moisture on their strength is of interest, and material was tested in order to bring out this relation.

The relative value of fire-killed timber and of timber cut from growing trees has been the subject of much discussion. Since considerable dead timber is used in the mines, and a large supply is available, tests on this kind of material were included, with the idea of determining its strength in the round form for comparison with material cut green.

MATERIAL.

The material tested[2] consisted of round beams and of props and caps representative of the market run of timber used in the coal mines. The props were from 5 to 6 inches in diameter and 6 feet long; the caps from 5 to 6 inches in diameter and 8 feet long; the beams nominally 8, 10, and 12 inches in diameter and 16 feet long. Table 1 gives a list of the material tested, and shows the form and number of

[1] This paper is of interest to miners and producers of mine timbers and will be suitable for distribution in Idaho, Montana, Wyoming, Colorado, Nevada, Arizona, and New Mexico.

[2] The material for the tests described in this report was in part donated by the Northern Coal & Coke Co. of Denver and in part obtained from several national forests located in Colorado. The tests were made at the timber-testing station of the Forest Service, which is conducted in cooperation with the University of Colorado, at Boulder.

the specimens, the kind of wood, the locality where secured, and the number of the table in which the individual tests are recorded.

TABLE 1.—*Material tested.*

Species and form of material.	Individual test records given in—		Number of pieces.	Source.
	Table No.	Reference Nos.		
Lodgepole pine (shipment A):				
Round props	11	1 to 10	15	Yards of Northern Coal & Coke Co., at Louisville, Colo. Probably cut on the west slope of the divide in Colorado.
	12	1 to 5		
Caps	13	1 to 10	15	Do.
	14	1 to 5		
Lodgepole pine (shipment B):				
Round props	11	11 to 20	15	Yards of Northern Coal & Coke Co. Probably cut on east slope of the divide in Boulder Co., Colo.
	12	6 to 10		
Caps	13	11 to 20	15	Do.
	14	6 to 10		
Lodgepole pine:				
Beams	15	1 to 30	45	Gunnison National Forest, Colo. (Cut from live timber.)
	16	1 to 15		
Lodgepole pine (fire killed):				
Beams	15	1 to 15	45	Gunnison National Forest, Colo. (Cut from timber standing dead for 30 years.)
	16	1 to 30		
Alpine fir:				
Round props	11	1 to 9	12	Partly from yards of Northern Coal & Coke Co., partly from Arapahoe National Forest, Colo.
	12	1 to 3		
Caps	13	1 to 9	14	Do.
	14	1 to 5		
Engelmann spruce:				
Round props	11	1 to 11	18	Partly from yards of Northern Coal & Coke Co., partly from Pike National Forest, Colo.
	12	1 to 7		
Caps	13	1 to 11	16	Do.
	14	1 to 5		
Douglas fir:				
Round props	11	1 to 10	15	Partly from yards of Northern Coal & Coke Co., partly from Gunnison National Forest.
	12	1 to 5		
Caps	13	1 to 10	15	Do.
	14	1 to 5		
Bristle-cone pine:				
Round props	11	1 to 10	15	Pike National Forest, Colo.
	12	1 to 5		
Caps	13	1 to 10	15	Do.
	14	1 to 5		
Western yellow pine (shipment A):				
Round props	11	1 to 10	15	Pike National Forest, Colo. (Shipped as "Black Jack.")
	12	1 to 5		
Caps	13	1 to 10	15	Do.
	14	1 to 5		
Western yellow pine (shipment B):				
Round props	11	11 to 20	15	Partly from yards of Northern Coal & Coke Co., partly from Gunnison National Forest.
	12	6 to 10		
Caps	13	11 to 20	15	Do.
	14	6 to 10		

The material from the National Forests was received at the laboratory in a green condition. The timbers from the yards of the coal company were partially air-dried. Upon arrival at the testing station all green material was barked and some of the specimens were soaked in water, while others were piled to air-season. The object of the water-soaking was to keep the timber in a green condition until tested or, in the case of the dead beams, to increase the moisture content to a point which would enable them to be compared with green material. The material cut green and water-soaked is used as the basis for making the comparisons with air-dry material.

The water-soaked material was placed in a small pond during the summer months and the first tests were made after 60 days and the last after 125 days of soaking. No means were available to give complete submersion. The caps and props were tied in bundles of five and the beams were rafted, iron rails being used to help submerge a part of the material. At intervals of two or three days the bundles and the individual beams were turned to make the soaking as uniform as possible.

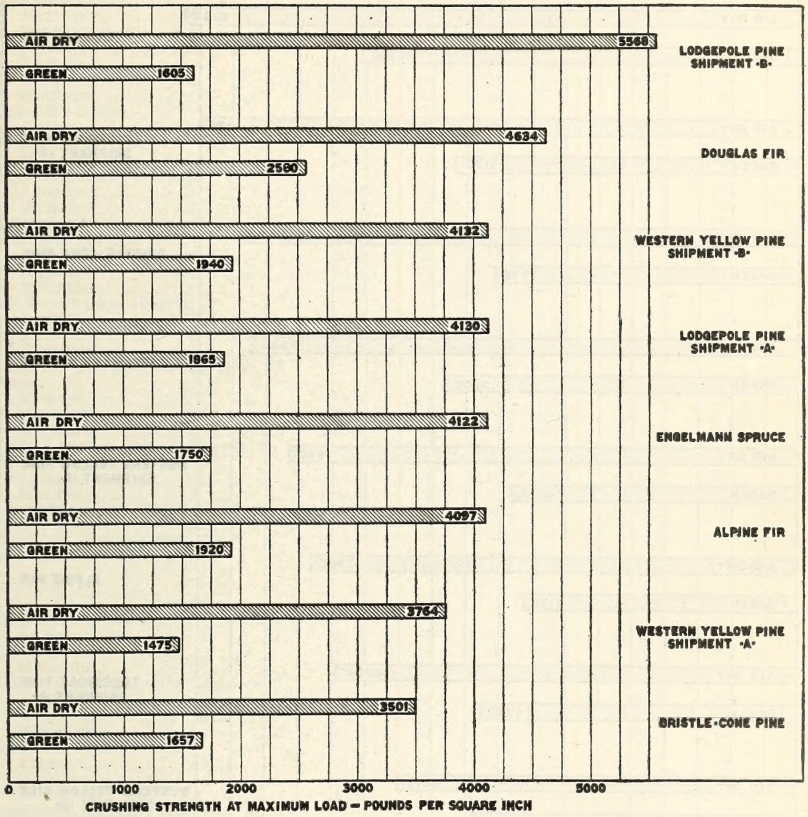


FIG. 1.—Comparison of different species; 6-inch round mine props—air-dried and green.

RESULTS OF TESTS.

Summaries of the results of the tests showing the average, maximum, and minimum of each group are presented in Tables 2 (props), 3 (caps), and 4 (beams). Results of the individual tests on the green props are recorded in Table 11, on the air-seasoned props in Table 12, on the caps in Tables 13 and 14, and on the beams in Tables 15 and 16.

PROPS AND CAPS.

The relative strength of air-seasoned and green material for each species and the relative strength of the different species are shown

graphically in figures 1 and 2. The increase in strength of the props due to seasoning is very evident in each species, and the average strength of the seasoned props of all species is 2.3 times that of the green ones at both maximum load and elastic limit. In the case of the caps the average strength of the dry timbers at the maximum load is 1.6 and at elastic limit 2.2 times the strength of the green timbers. While at the elastic limit the influence of the moisture

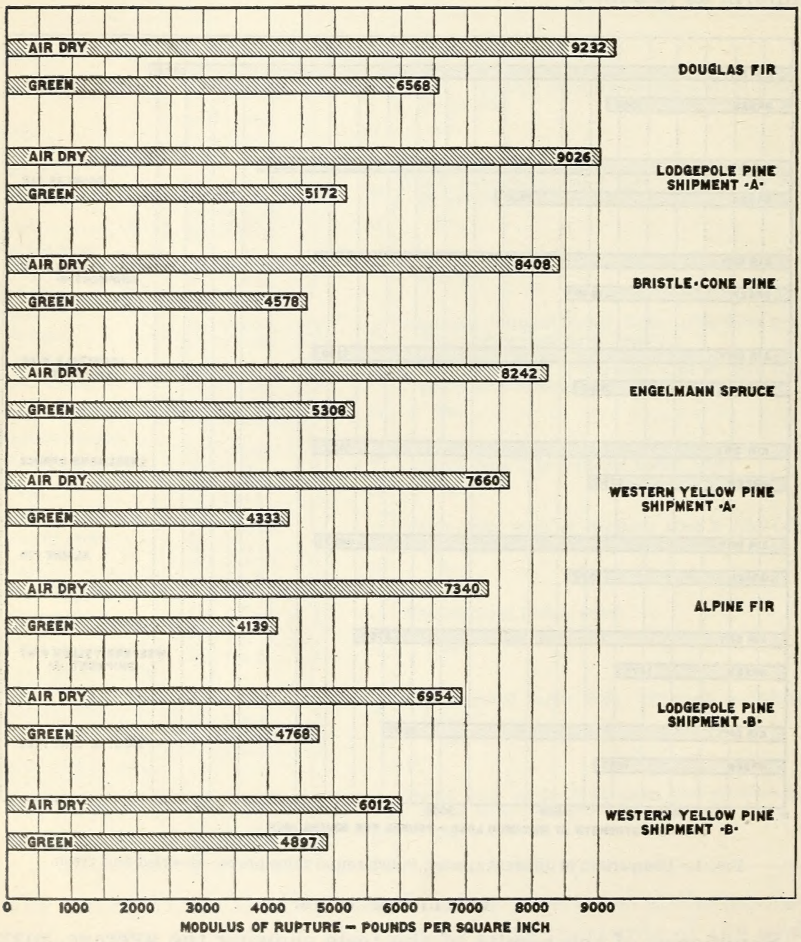


FIG. 2.—Comparison of different species; 6-inch round mine caps—air-dried and green.

was practically the same for both the crushing and bending tests, at the maximum load it is much more pronounced in the crushing tests. Stiffness in bending was increased by seasoning to 1.4 times the green value. There appears to be no marked variation in this strength ratio among the various species tested. It is slightly below the average in Douglas fir, due to the consistently high values for the green material in comparison with the other species.

TABLE 2.—*Summary of crushing tests on round mine props (nominal size, 5-inch top by 6 feet long).*

GREEN (WATER SOAKED).

Species, number of tests.	Moisture.	Rings per inch.	Diameter.		Crushing strength at maximum load.	Crushing strength at elastic limit.	Modulus of elasticity.
			Top.	Butt.			
	Per cent.		*Inches.*	*Inches.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*	*1,000 lbs. per sq. in.*
Lodgepole pine (shipment A); 10 tests:							
Average	75.7	40	5.73	6.18	1,865	1,495	599
Maximum	102.0	56	6.13	6.92	2,285	1,981	839
Minimum	48.3	28	4.93	5.33	1,440	1,049	343
Lodgepole pine (shipment B); 10 tests:							
Average	70.8	43	5.90	6.58	1,605	1,240	496
Maximum	108.2	58	7.00	7.56	1,890	1,559	621
Minimum	57.5	31	4.85	6.05	1,169	866	387
Alpine fir; 9 tests:							
Average	91.0	26	4.90	5.65	1,920	1,490	541
Maximum	123.6	42	5.37	6.05	2,355	1,944	706
Minimum	38.6	13	4.62	5.38	1,573	1,268	401
Engelmann spruce; 11 tests:							
Average	62.3	32	4.95	5.80	1,750	1,347	529
Maximum	89.1	46	6.20	7.08	2,115	1,755	686
Minimum	38.1	19	4.14	5.09	1,511	1,062	358
Douglas fir; 10 tests:							
Average	50.5	39	5.48	6.05	2,580	2,130	758
Maximum	91.6	76	6.84	7.16	2,870	2,438	865
Minimum	30.0	17	4.93	5.41	2,200	1,885	596
Bristle-cone pine; 10 tests:							
Average	85.9	35	4.58	5.38	1,657	1,310	508
Maximum	109.0	43	5.33	6.40	2,026	1,590	638
Minimum	56.1	31	3.98	4.77	1,364	965	390
Western yellow pine (shipment A); 10 tests:							
Average	96.1	14	4.44	5.20	1,475	1,201	443
Maximum	116.1	16	4.78	5.60	1,681	1,412	516
Minimum	83.2	13	4.14	4.94	1,269	1,038	345
Western yellow pine (shipment B); 10 tests:							
Average	82.0	18	5.35	6.00	1,940	1,450	561
Maximum	113.2	32	5.65	6.17	2,410	1,883	762
Minimum	54.8	11	5.01	5.73	1,668	1,132	448

AIR SEASONED.

Lodgepole pine (shipment A); 5 tests:							
Average	11.5	46	4.93	5.43	4,130	3,513	993
Maximum	12.3	57	5.17	5.57	4,770	4,190	1,194
Minimum	11.0	34	4.77	5.17	3,340	2,750	875
Lodgepole pine (shipment B); 5 tests:							
Average	12.2	45	4.81	5.44	5,568	4,438	1,282
Maximum	15.9	50	5.25	5.73	6,340	4,980	1,452
Minimum	11.0	42	4.01	5.01	4,980	4,010	1,135
Alpine fir; 3 tests:							
Average	11.6	18	4.27	5.28	4,097	3,530	978
Maximum	12.4	23	4.46	5.41	4,260	3,875	1,043
Minimum	10.5	15	4.06	5.09	3,910	3,165	890
Engelmann spruce; 7 tests:							
Average	11.8	33	4.42	5.29	4,122	3,297	1,042
Maximum	13.7	50	5.09	5.97	5,560	4,290	1,321
Minimum	10.9	16	3.50	4.62	2,990	2,410	703
Douglas fir; 5 tests:							
Average	12.3	49	4.85	5.33	4,634	3,617	1,131
Maximum	13.7	76	5.33	6.05	5,720	4,450	1,324
Minimum	11.5	28	4.30	4.62	2,960	2,340	873
Bristle-cone pine; 5 tests:							
Average	12.4	38	3.68	4.44	3,501	2,823	826
Maximum	12.6	45	3.98	4.85	4,390	3,512	1,023
Minimum	12.2	30	3.18	4.22	2,340	2,013	628
Western yellow pine (shipment A); 5 tests:							
Average	11.7	14	3.93	4.78	3,764	3,401	887
Maximum	13.4	16	4.30	4.85	5,330	4,780	1,146
Minimum	10.5	11	3.50	4.62	3,050	2,470	626
Western yellow pine (shipment B); 5 tests:							
Average	11.7	18	4.82	5.44	4,132	3,266	956
Maximum	13.0	31	4.93	5.65	4,790	3,770	1,160
Minimum	10.9	12	4.62	5.25	3,120	2,270	628

TABLE 3.—*Summary of bending tests on round mine caps (nominal size, 5-inch top by 8 feet long; span, 7 feet; third-point loading).*

GREEN (WATER SOAKED).

Species, number of tests.	Moisture.	Rings per inch.	Diameter.		Modulus of rupture.	Fiber stress at elastic limit.	Stiffness factor $\left(\frac{P}{Id}\right)$
			Top.	Butt.			
Lodgepole pine (shipment A); 10 tests:	*Per cent.*		*Inches.*	*Inches.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*	
Average	89.3	43	5.59	6.20	5,172	3,104	98.0
Maximum	133.3	61	5.90	6.68	6,460	3,830	119.7
Minimum	56.7	23	5.17	5.60	4,040	2,635	72.1
Lodgepole pine (shipment B); 10 tests:							
Average	60.6	43	5.78	6.45	4,768	2,762	86.0
Maximum	89.5	52	6.00	6.75	6,180	3,555	126.2
Minimum	40.1	31	5.25	6.00	3,585	2,090	55.3
Alpine fir; 9 tests:							
Average	99.5	21	4.65	5.72	4,139	2,450	79.3
Maximum	147.2	36	5.63	6.50	5,260	2,910	108.8
Minimum	57.6	8	4.13	5.38	1,945	1,782	57.6
Engelmann spruce; 11 tests:							
Average	54.3	30	5.16	6.40	5,308	2,709	95.0
Maximum	74.6	45	6.00	7.00	7,280	3,665	130.5
Minimum	36.3	17	4.44	5.88	3,500	1,991	68.2
Douglas fir; 10 tests:							
Average	69.4	27	4.78	5.66	6,568	3,455	85.2
Maximum	119.1	38	6.25	7.00	7,310	4,675	107.9
Minimum	32.6	16	4.00	5.00	4,840	2,505	55.0
Bristle-cone pine; 10 tests:							
Average	74.3	37	4.63	5.62	4,578	2,459	66.6
Maximum	96.1	62	5.63	7.00	5,480	3,960	85.7
Minimum	66.2	25	3.38	4.00	3,500	1,666	48.3
Western yellow pine (shipment A); 10 tests:							
Average	88.5	13	4.39	5.60	4,333	2,170	74.5
Maximum	106.3	15	4.80	6.25	4,960	2,775	86.9
Minimum	71.1	12	3.75	4.75	3,860	1,553	59.1
Western yellow pine (shipment B); 10 tests:							
Average	147.1	26	4.42	5.45	4,897	2,890	72.6
Maximum	198.4	42	5.00	6.12	6,190	3,540	89.8
Minimum	86.5	15	3.62	5.00	3,320	2,148	35.9

AIR SEASONED.

Lodgepole pine (shipment A); 5 tests:							
Average	11.4	54	4.76	5.21	9,026	6,600	133.1
Maximum	11.9	72	5.09	5.49	11,630	8,640	152.2
Minimum	10.6	33	4.54	5.09	7,180	4,790	119.5
Lodgepole pine (shipment B); 5 tests:							
Average	11.1	44	4.84	5.49	6,954	5,962	114.5
Maximum	11.7	47	5.41	5.73	9,620	7,290	148.2
Minimum	10.6	42	4.54	5.33	4,490	4,230	84.1
Alpine fir; 5 tests:							
Average	11.4	26	4.22	5.28	7,340	5,460	108.5
Maximum	12.1	37	4.62	5.57	9,350	6,600	125.2
Minimum	10.4	20	3.66	5.09	5,270	4,320	85.2
Engelmann spruce; 5 tests:							
Average	10.9	37	4.41	5.35	8,242	6,618	118.5
Maximum	11.8	45	5.33	6.05	9,900	7,340	151.2
Minimum	8.8	27	3.50	4.62	6,260	5,190	72.0
Douglas fir; 5 tests:							
Average	11.8	23	4.30	5.20	9,232	6,842	126.3
Maximum	12.3	29	4.77	5.57	10,960	7,660	145.1
Minimum	11.4	15	3.82	4.77	5,790	5,100	92.8
Bristle-cone pine; 5 tests:							
Average	11.5	37	3.82	4.98	8,408	5,684	97.7
Maximum	12.5	52	4.22	5.25	9,550	6,700	116.1
Minimum	10.7	27	3.50	4.54	7,000	4,120	89.3
Western yellow pine (shipment A); 5 tests:							
Average	10.3	14	3.58	4.85	7,660	5,770	103.8
Maximum	10.6	15	3.66	5.09	9,770	7,730	118.2
Minimum	9.4	13	3.50	4.62	5,660	3,870	87.5
Western yellow pine (shipment B); 5 tests:							
Average	10.7	21	3.90	5.12	6,012	4,938	80.0
Maximum	11.4	26	4.22	5.41	7,360	5,830	112.6
Minimum	10.3	17	3.58	4.62	4,210	4,220	62.2

TABLE 4.—*Summary of bending tests on round beams, 16 feet long (span, 15 feet; third-point loading).*

GREEN (WATER SOAKED).

Species, size, number of tests.	Moisture.	Rings per inch.	Diameter.		Modulus of rupture.	Fiber stress at elastic limit.	Stiffness factor $\left(\frac{P}{ld}\right)$	Work to maximum load.
			Top.	Butt.				
Lodgepole pine, cut from live timber:					*Lbs. per sq. in.*	*Lbs. per sq. in.*		*Inch lbs. per cu. in.*
8-inch butt, 10 tests—	*Per cent.*		*Inches.*	*Inches.*				
Average	77.3	32	6.77	8.20	5,348	3,120	10.99	4.7
Maximum	99.4	37	7.32	8.75	6,210	4,200	13.42	6.6
Minimum	62.1	28	6.29	7.76	4,860	2,425	9.26	2.6
10-inch butt, 10 tests—								
Average	90.2	27	8.26	9.97	5,233	3,008	10.32	5.5
Maximum	118.2	32	9.23	10.74	6,230	3,905	11.73	7.8
Minimum	73.4	21	7.24	9.39	4,510	2,038	7.48	3.2
12-inch butt, 10 tests—								
Average	91.8	23	9.82	11.62	5,095	2,987	10.23	5.2
Maximum	99.6	24	10.82	12.41	6,270	3,780	13.70	7.0
Minimum	78.3	18	9.23	10.98	4,230	2,298	8.16	2.0
Lodgepole pine, cut from timber after standing dead for 30 years:								
8-inch butt, 5 tests—								
Average	38.1	44	7.00	8.50	5,448	2,905	10.38	5.3
Maximum	45.2	52	7.08	9.06	6,580	3,690	13.25	7.6
Minimum	35.0	34	6.92	7.80	3,570	2,210	8.00	2.3
10-inch butt, 5 tests—								
Average	40.1	40	8.21	10.24	4,940	2,950	8.84	3.4
Maximum	47.7	48	9.23	11.14	6,500	4,180	10.97	5.4
Minimum	29.8	35	7.56	9.71	3,870	1,592	7.09	1.6
12-inch butt, 5 tests—								
Average	37.2	28	10.00	12.47	4,430	2,320	7.71	4.3
Maximum	41.7	34	10.98	12.97	5,680	2,960	9.71	8.2
Minimum	27.8	24	9.31	11.77	3,820	1,828	5.18	2.0

AIR SEASONED.

Lodgepole pine, cut from live timber:								
8-inch butt, 5 tests—								
Average	16.8	32	6.99	8.04	7,748	5,018	14.05	3.8
Maximum	19.9	34	7.64	8.36	9,310	5,290	16.80	4.9
Minimum	15.2	29	6.37	7.64	7,160	4,640	12.43	2.7
10-inch butt, 5 tests—								
Average	17.1	25	8.09	9.77	6,948	4,816	13.33	3.1
Maximum	18.3	27	8.59	10.03	9,060	5,940	18.75	4.0
Minimum	14.6	23	7.08	9.55	4,480	3,190	10.31	1.5
12-inch butt, 5 tests—								
Average	19.3	22	9.73	11.51	5,409	3,741	9.57	2.3
Maximum	21.8	23	9.95	11.81	6,350	4,340	11.62	3.0
Minimum	17.7	21	9.55	11.14	3,745	2,875	6.85	1.2
Lodgepole pine, cut from timber after standing dead for 30 years:								
8-inch butt, 9 tests—								
Average	13.7	40	6.98	8.39	5,625	4,649	10.92	2.1
Maximum	14.6	51	7.64	8.91	7,780	6,720	12.51	5.6
Minimum	11.5	34	6.45	7.48	3,843	3,195	9.58	.8
10-inch butt, 10 tests—								
Average	12.9	34	8.27	10.11	5,166	4,489	10.54	2.3
Maximum	14.4	42	8.91	10.66	8,970	6,400	13.53	4.2
Minimum	12.1	24	7.64	9.31	2,690	2,585	8.06	.5
12-inch butt, 11 tests—								
Average	13.8	31	9.16	12.15	4,720	3,925	9.84	1.7
Maximum	16.6	37	11.14	12.49	7,310	5,960	12.29	3.8
Minimum	12.0	24	9.07	11.46	2,060	1,343	8.12	.4

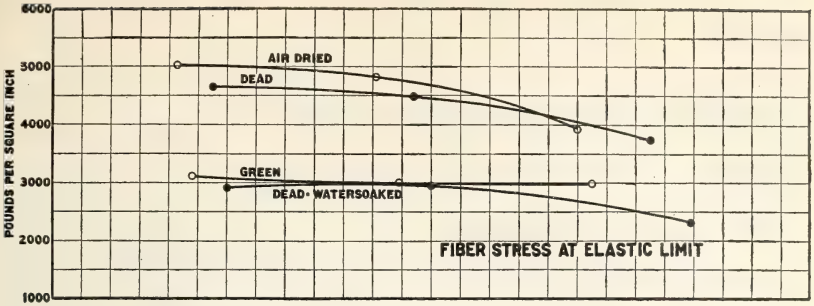
The average results do not show a consistent difference in the relative strength of the various species tested. Figures 1 and 2 show that, with the exception of the green props and caps of Douglas fir and the dry props of lodgepole pine (Shipment B), there is not a very large difference in the strength of the various shipments. It

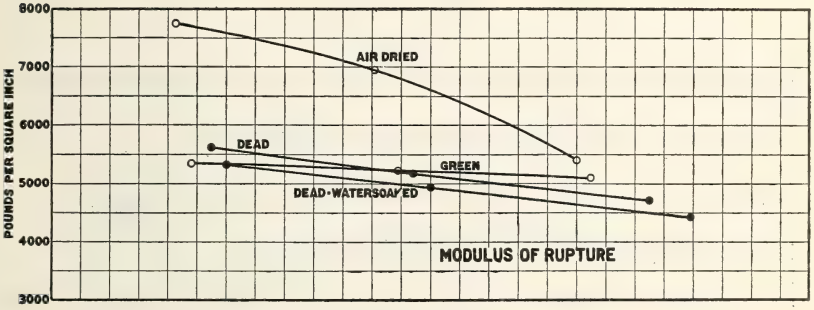
is apparent from the various positions occupied by the different shipments of lodgepole pine and western yellow pine that species is not in itself a reliable guide to strength in the selection of material of this form and size. With clear material, consistent differences would probably be found between some of the species, but in the props especially the degree of straightness of the piece and the presence of knots seem of greater effect than the species.

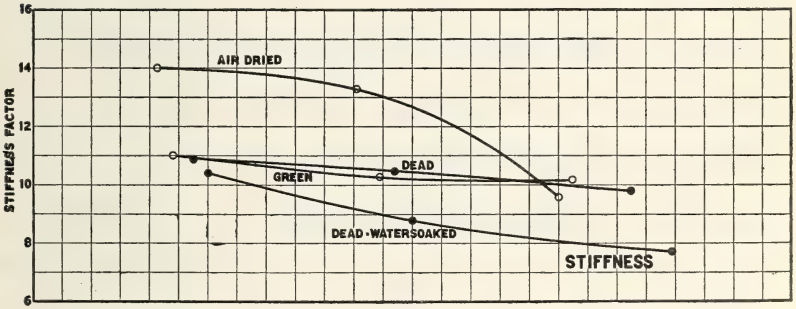
BEAMS.

The results of the tests on the three sizes of 16-foot round beams of lodgepole pine are shown graphically in figures 3 and 4. With the exception of the work to maximum load, all the strength functions decrease in value with increase in the diameter of the beam. The amount of this variation differs in the different kinds of material, being least in the green, greatest in the air-dried, and intermediate in the dead timber. The reason for the decrease in the unit strength of the larger beams is not apparent. It is not due to visible defects, such as cause a decrease in the unit stress in large stringers when compared with small clear pieces cut from them, since the defects in the 8 and 12 inch beams did not differ in kind or in appearance. The fact that stiffness decreases in the same manner as strength corroborates this statement, since such defects as knots and checks do not generally affect stiffness up to the elastic limit. The difference may, however, be due, at least in part, to rate of growth, which increases in all cases with increase in diameter. The smaller beams were apparently cut from the suppressed growth of a fairly even-aged stand. The unit weight of the beams does not vary consistently with the strength. The dry weight per cubic foot of the air-dried beams is lowest in the 12-inch size, but for the dead beams the weight is highest in this size.

The relative values of the dead, green, and air-dried timbers are also indicated in figures 3 and 4. In strength the dead material falls between that of the air-dried and green, being close to the air-dried at the elastic limit and close to the green at the maximum load. The air-dried material is the stiffest, the green and dead having practically equal values for this factor. The closeness of the values for green and dead water-soaked material and a comparison of their curves with those of the dry timbers show very clearly the effect of moisture in reducing the stiffness and strength at the elastic limit. In work to maximum load, which is an indication of toughness, the order of the curves is reversed, the green and water-soaked beams having values about twice as great as the dry material. The position of the dead water-soaked beams, especially, brings out the fact that the greater brittleness of the dead or air-dried material is due to dryness and not to a deterioration of the wood. Drying the beams







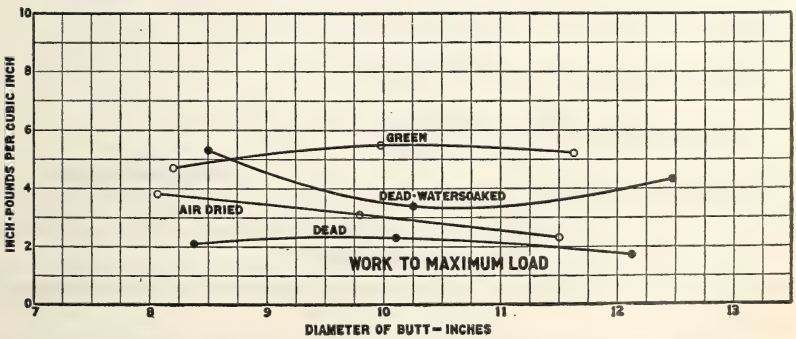


FIG. 3.—Relation of unit strength of 16-foot round beams to diameter and condition.

increased the strength and stiffness of the wood but decreased its toughness.

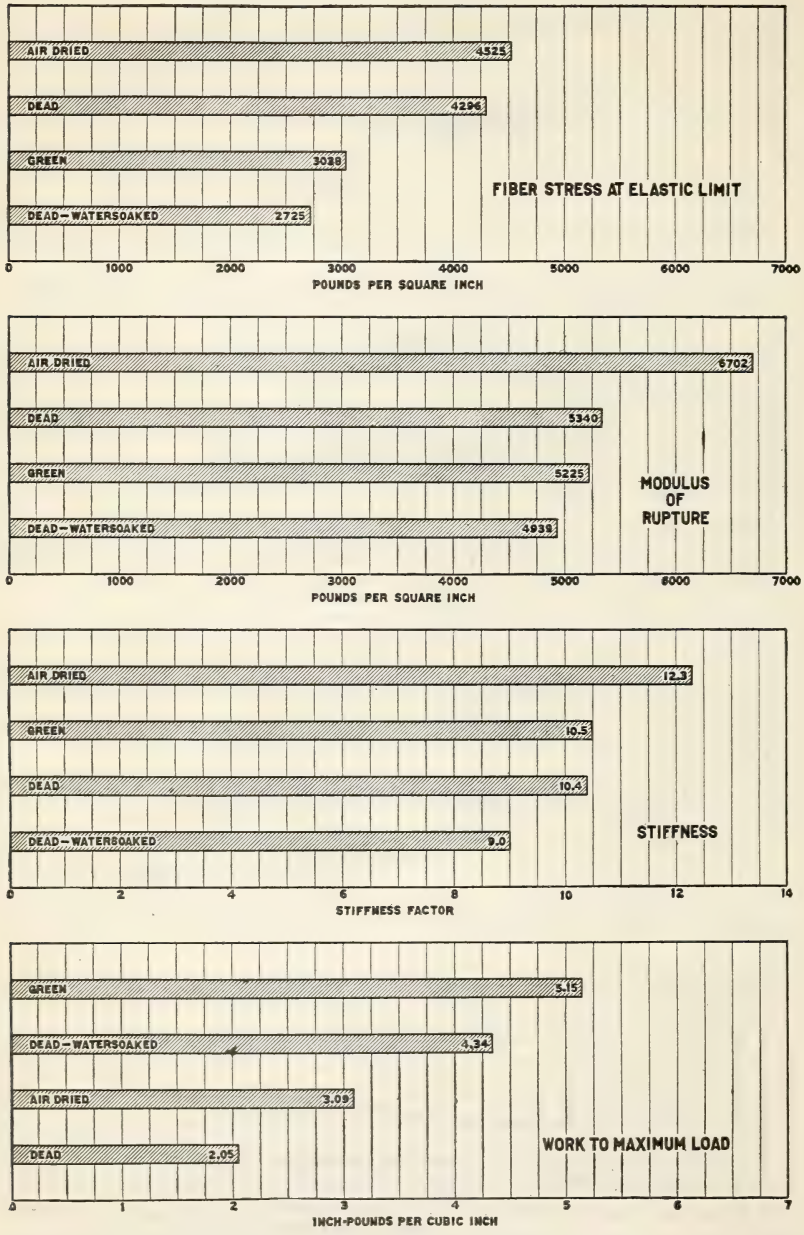


FIG. 4.—Relation of unit strength of 16-foot round beams to condition; based on average values of the three sizes tested.

In comparing fire-killed and green material, the grade of both, in regard to ordinary defects, should be taken into consideration. The

dead material tested was cut from an area supposedly burned over in 1880. In general, the surface was covered with a network of shallow worm marks (made when the bark was on and probably of no influence on the soundness). The beams, even the larger ones, were very rough and knotty, and were of poorer grade in respect to condition of knots than those cut green. The cross sections in general were sound, though here and there along the length were places beginning to form punky pockets at the surface. The fact that this material under test gave values up to the elastic limit nearly equal to those of the air-dried beams is of considerable interest, as it indicates that it is in excellent condition for the uses to which round material is ordinarily put.

CONCLUSIONS.

The tests indicate that:

1. An air-dried mine prop is superior to a green one as follows:
   Strength at elastic limit 2.3 times as great.
   Strength at maximum load 2.3 times as great.
   Stiffness 1.9 times as great.
   An air-dried mine cap is superior to a green one as follows:
   Strength at elastic limit 2.2 times as great.
   Strength at maximum load 1.6 times as great.
   Stiffness 1.4 times as great.
2. With the exception of Douglas fir, there seems to be as much variation in the strength of one species procured in different places as among the different species themselves. This is probably the result of defects such as checks, knots, and bends, which, in this size of material (5 to 6 inch diameter round caps and props), apparently overbalance the differences in the actual strength of the clear wood.
3. The unit strength and stiffness of 16-foot round beams decrease with an increase in size. The smaller beams tested, however, represented a slower growth material and were probably suppressed trees.
4. Beams cut from timber standing dead for about 30 years showed a strength intermediate between green and air-dried material cut from live timber. The tests tend to corroborate the opinion that timber cut from dead trees can be graded on the same basis as other material; that is, the quality of the wood has not changed, from the fact that it has seasoned on the stump, and deterioration, if present, will be indicated by signs of decay. Checking in material to be used in the round form can hardly be considered as a defect, as it occurs in all air-dried round material.

CONSUMPTION AND DURABILITY.

CONSUMPTION OF MINE TIMBERS IN COLORADO.

The statistics here presented were collected to show the consumption of timber by the mining industry of Colorado [1] in 1911. They were obtained by sending a card to the mine operators of the State, requesting them to furnish the amounts, costs, and species of tim-

[1] Colorado was chosen partly because of its importance as a mining State; partly because for the year 1911 an estimate of the entire production of wood products, including lumber, poles, crossties, round mine timbers, and fuel was also available for direct comparison, and partly because the State is near the center of distribution of the species of mine timbers tested.

ber used in the mines, and information concerning the life of the timber and the extent to which methods to prevent decay had been employed. A small part of the material included may have been used in structures above ground.

Reports were requested from 823 operators, 110 of whom were coal-mine and 713 metal-mine operators. Out of 352 replies, 179 (15 coal-mine and 164 metal-mine operators) reported that no timber was used during 1911, while 173 operators reported the use of timber on which the following statistics are based.

In addition to the material reported by the tables, about 1,745 cords (or 872,500 b. m.) were used for fuel.

Nearly all the timber used came from within the State. About 800,000 board feet was reported as coming from outside, mostly Douglas fir from Oregon, with a small amount of pine from New Mexico.

The timbers for use in the coal mines ranged in size from about 5 to 7 inches in diameter and from 7 to 18 feet in length. In the metal mines 8 to 10 inch diameters were the principal sizes, though timbers varying from 6 to 20 inches were reported. Lagging was usually 3 to 4 inches at the small end, and mine ties were 4 by 4 or 4 by 5 inches in section and from 36 inches in length in the metal mines to 54 inches in the coal mines.

TABLE 5.—*Amounts and values of mine timbers used in Colorado in 1905, based on reports of mine operators.*

Mines reporting.	Number of mines.	Total amounts.		Total values.		Cost per M b. m.	
		Round, M b. m.	Sawed, M b. m.	Round.	Sawed.	Round.	Sawed.
Coal mines	69	7,893	457	$153,152	$15,428	$19.40	$33.76
Metal mines	418	18,152	13,061	284,861	251,798	15.69	19.28
Total (all mines)	487	26,045	13,518	438,013	267,226	16.82	19.77
Aggregate		39,563 M b. m.		$705,239			

TABLE 6.—*Amounts and values of mine timbers used in Colorado in 1911, based on reports of mine operators.*

Mines reporting.	Number of mines.	Total amounts.		Total values.		Cost per M b. m.	
		Round, M b. m.	Sawed, M b. m.	Round.	Sawed.	Round.	Sawed.
Coal mines	77	10,859	1,000	$307,372	$20,368	$28.20	$20.37
Metal mines	187	6,601	6,406	139,030	141,185	21.10	22.00
Total (all mines)	264	17,460	7,406	446,402	161,553	25.50	21.80
Aggregate		24,866 M b. m.		$607,955			

The amounts were reported in linear feet, in board feet (log scale), in cubic feet, and in cords. To reduce these various units to the

same basis 6 board feet were considered equivalent to 1 cubic foot of round timber and 500 board feet to a cord.

Table 5 is compiled from Forest Service Circular 49 for purposes of comparison. Table 6 gives similar data obtained for 1911. The two tables are not directly comparable, however, since the proportion of timber used by the mines reporting, to the whole consumption in the State, is not definitely known in either case.

PRODUCTION OF MINE TIMBERS IN COLORADO.

A study of timber products was made in Colorado for the year 1911, and this furnishes some basis for an estimate of the probable total consumption of timber by the mines, including both round and sawed forms. The total production, including lumber, crossties, mine timbers, poles, fuel, and farm timbers, on the basis of the reports of the national forest supervisors, for both Government and private lands, was 222,808,000 board feet. The total production of round mine timbers was 36,274,000 board feet. The consumption reported, as shown in Table 6, was 17,460,000 feet of round material and 7,406,000 feet of sawed lumber. If the figure for production may be assumed as approximately correct for the actual total consumption and the proportion between the amounts of sawed and round forms reported holds for the total consumption, the total sawed timber used in the mines would be 15,370,000 feet and the total timber, round and sawed, would be 51,644,000 feet. This represents close to $1,250,000 in total value and 23 per cent of all the timber produced in the State.

PRODUCTION BY SPECIES.

The relative amounts of the different species used could not be obtained from the reports submitted by the mine operators. Based upon production, however, a close estimate is given in Table 7. The local names for certain species are different from those adopted by the Forest Service, and in order to make clear what woods are referred to, the scientific name, the common name used by the Forest Service, and the name used locally in Colorado are given below:

Scientific name.	*Common name used by Forest Service.*	*Common name used locally.*
Pinus contorta.	Lodgepole pine.	White pine.
Pinus ponderosa	Western yellow pine.	Black jack and yellow pine.
Pinus flexilis.	Limber pine.	
Pinus aristata.	Bristle-cone pine.	Fox-tail pine.
Pseudotsuga taxifolia.	Douglas fir.	Red spruce.
Picea engelmanni.	Engelmann spruce.	White spruce.
Picea parryana.	Blue spruce.	Water spruce.
Abies lasiocarpa.	Alpine fir.	Balsam.
Abies concolor.	White fir.	Black balsam.
Populus tremuloides.	Aspen.	Quaking-asp.

TABLE 7.—*Amounts by species of round mine timbers produced in Colorado in 1911.*

Species.	Amount.	Percentage of total.
	Board feet.	
Lodgepole pine	23,421,000	65
Engelmann spruce	8,242,000	23
Douglas fir	2,244,000	6
Western yellow pine	1,354,000	4
Limber pine	431,000	1
Bristle-cone pine	183,000	1
Aspen	149,000	
Alpine fir	109,000	
Blue spruce	75,000	
White fir	65,000	
Oak	1,000	
Total	36,274,000	100

TABLE 8.—*Unit costs for various diameters.*

Diameter.	Cost per piece 16 feet long.	Cost per linear foot.	Cost per inch of diameter 16 feet long.
Inches.			
3	$0.35	$0.022	$0.117
4	.40 to $0.50	.025 to $0.031	.100 to $0.125
6	.45 to .65	.028 to .041	.075 to .108
8	.60 to 1.25	.038 to .078	.075 to .156
10	1.15 to 1.60	.072 to .100	.115 to .160
12	1.50 to 2.15	.094 to .135	.125 to .180
14	2.00 to 2.25	.125 to .141	.143 to .161
16	2.50	.156	.156

Table 7 shows that lodgepole pine is the main source of supply for round mine timbers, and, together with Engelmann spruce, makes up 88 per cent of all the props cut. Douglas fir, although a very desirable wood, formed only 6 per cent of the total.

COSTS FOR DIFFERENT SIZES.

Table 8, giving costs for props of various diameters, was compiled from such data submitted by the operators as were definite in regard to the size of the material. Several methods of purchasing round material were reported—cost per piece for a given length and diameter, cost per linear foot for a given diameter, and cost per inch of diameter at the small end for a given length. A large majority reported the cost per linear foot.

LIFE OF TIMBERS.

There was a large variation in the reported life of timbers in the different mines, especially in the metal mines. The timbers in the coal mines had an average life of only about one-half that found in the metal mines, but their size was also only about one-half as great. Tables 9 and 10 give the average values obtained from statements of the operators.

TABLE 9.—*Reported life of untreated round mine timbers in coal mines (mostly 5 to 7 inches diameter).*

Conditions in mine.	Douglas fir.	Pine.[1]	Engelmann spruce.	Alpine fir.	Piñon.
	Years.	*Years.*	*Years.*	*Years.*	*Years.*
Average	5	4	4	3	4
Poor ventilation	2	1	1	.....	1
Good ventilation	10	8	8	.....	6
Exceptional	25	15	.....	10	.....

[1] Includes lodgepole pine and western yellow pine.

TABLE 10.—*Reported life of untreated round mine timbers in metal mines (mostly 8 to 10 inches diameter).*

Conditions in mine.	Douglas fir.	Western yellow pine.	Lodgepole pine.	Engelmann spruce.
	Years.	*Years.*	*Years.*	*Years.*
Average	9	9	7	8
Very poor ventilation	2 to 5	1 to 3	1 to 2	1 to 2
Constantly wet	20 to 40	15 to 25	.....	15 to 20

The conditions under which the estimates were made vary so much that the relative life of the different species is probably not reliable. For example, several operators reported that under the same conditions Douglas fir outlasts lodgepole pine or spruce two to three times; yet the average values show comparatively little variation among the species.

The factors that cause variation in the life of the timbers are principally ventilation, moisture, acid mine water, and the condition of the timbers when placed. The influence of fresh and comparatively dry air was clearly indicated in several mines which reported a life fully four times as long for the timbers in the intake shaft as for those in the return shaft (8 and 2 years, respectively). Several operators reported that they had increased the life of their timbers from two to three times by peeling and seasoning them before placement. Certain mines reported that their timbers were sound after standing from 25 to 35 years under conditions where they were nearly always wet, and in one or two cases the water was stated to contain "sulphuric acid" or "copper and arsenic," which probably acted as an antiseptic. Both constantly wet and constantly dry conditions appear, from the replies, to be favorable to a long life, while dampness, due to stagnant air, or alternating dryness and wetness, appears to furnish the best conditions for the growth of wood-destroying fungi.

PRESERVATIVE TREATMENT.

Preservative treatment to prevent decay was not regularly practiced at any of the mines reporting. Sixteen operators referred to some use of preservatives, though none had had a long enough experience to furnish data on the increased life from such treatment. The methods spoken of were dipping in creosote or crude oil, and brush

treatments with creosote, carbolineum, or crude oil. One operator referred to the disagreeable effect on the miners of the odor from the creosote in the mine.

There was great variation in the replies to the question regarding the proportion of timber used for replacements made necessary by decay. Replies from 30 coal mines averaged 11 per cent (14 reporting 0 per cent and none 100 per cent), and from 112 metal mines averaged 21 per cent (44 reporting 0 per cent and 11 reporting 100 per cent). It is apparent that the economy of preservative treatment is a local problem with each mine.

In order to decide whether it would be economical in any given case to apply treatment only a few factors concerning the present costs and life of the timbers are essential. The proper method[1] of treatment would depend upon species of wood, capacity of apparatus, and local conditions, but the preliminary steps could be taken on the basis of the following data:

1. The amount and cost of material that goes annually toward replacing decayed timbers.
2. The cost, in place, of the timbers used.
3. The average life of the timber.

The first of these factors will readily show whether the amount concerned is large enough to warrant further consideration of preservative treatment. In certain coal mines, where but few timbers are necessary in the permanent entries and where the majority of timbers are used in temporary positions, a brush treatment would probably be all that is warranted, unless impregnated material could be procured in the market. On the other hand, where a large amount of material is used to replace decayed timbers the installation of a small treating plant might be seriously considered.

From the cost in place and the average life of the timbers there can be calculated an annual charge, a measure of the relative economy, with which any other combination of cost and life (such as that resulting from a preservative treatment of the timber or perhaps from the use of some other kind of material) can be compared. In figure 5 is presented a series of curves, each for a definite initial cost of a timber or set of timbers, which show the relation between *length of life* and *annual charge* when compound interest on the investment is considered and maintenance is assumed for an indefinite time.[2]

[1] Forest Service Bulletin 107, The Preservation of Mine Timbers, by E. W. Peters, treats of various methods of preserving mine timbers from decay.

[2] The annual charges are figured on this basis so that a fair comparison can be made between different methods involving various combinations of costs and length of service. If a material were placed that would last forever its annual charge would be simply the interest on the cost in place. If the material must be replaced every so often, the annual charge represents the interest on a sum of money which, if placed at compound interest, would pay for the initial cost in place and all future replacements and would be itself used up at the end of the period of maintenance under consideration. If this period be of an indefinite length (forever), the annual charge is the interest on a sum of money sufficient to pay the present cost of installation and, by the accumulation of compound interest on the balance, take care of future replacements at the assumed intervals of time.

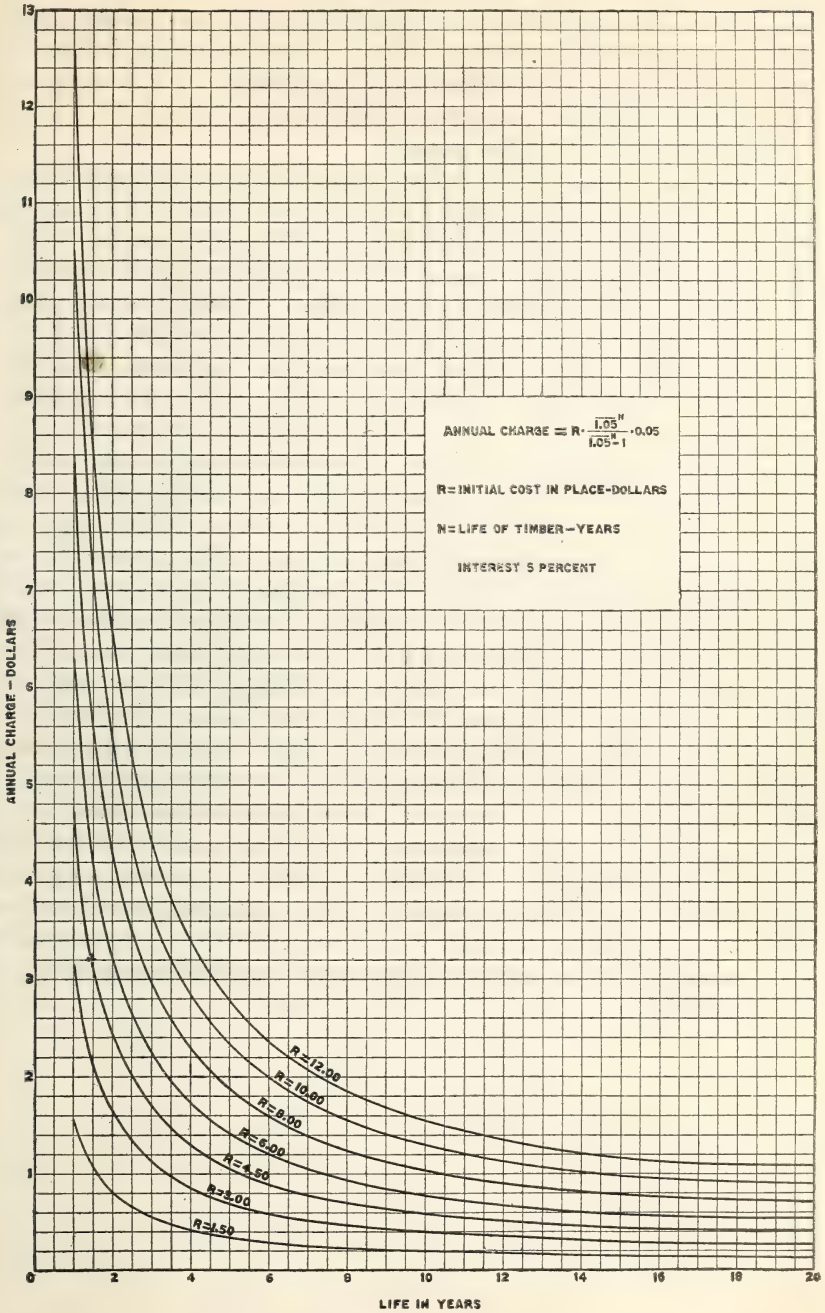


FIG. 5.—Relation between life of timbers and annual charge.

The curves will show how much additional initial cost is warranted when a given increase in life due to the treatment under consideration is assumed and the initial cost and life for the existing conditions are known. The diagram also illustrates graphically, by the steepness of the curves, the great economy in prolonging the life of timbers that ordinarily last but a few years.

To illustrate the use of the curves, assume that an operator wants to find out approximately what saving he would effect by carrying out some proposed scheme to lengthen the life of his timbers in certain permanent openings. Assume that each timber set costs $6, including the expense of framing and setting. If its life is five years, its annual charge as shown by the curves is approximately $1.40. Let us next assume that the proposed treatment will double the life; that is, give the timbers a service of 10 years. A further inspection of the curves at the line of 10 years' life shows that the same annual charge of $1.40 results from an initial cost of $10.50. In other words, the economy of a timber that costs $6 in place and lasts five years is the same as one that costs $10.50 and lasts 10 years; and, therefore, the proposed treatment would pay if the final cost of the treated timber was anything less than $10.50. If we assume the cost of the treatment to be $1.50 for each timber (making the total cost in place $7.50) the annual charge would be about $1. The cost of using treated timbers would increase the total cost of timbering each year until the period of the natural (untreated) life of the timbers (five years in this example) had been passed; after that time, however, there would be a period of very low total costs until it was necessary to replace the treated material. The economy shown in an annual charge of $1 in comparison with $1.40 represents the average conditions due to a continuous maintenance. It means, expressed in another way, that the investment required to maintain the untreated timber permanently would be $28, and that the investment for the maintenance of the treated timber would be $20, under the conditions given in this example.

APPENDIX.

METHODS.

TESTING.

The 6-foot props were tested in compression parallel to the grain at a speed of 0.119 inch per minute. A bearing block was used between the prop and the base of the machine. The compression of the prop, as indicated by the movement of the head of the testing machine, was read to thousandths of an inch by means of an Olsen deflectometer. Figure 6 shows a prop in the testing machine after failure.

The 8-foot caps were tested on a 7-foot span with third-point loading. The tests were made on a 200,000-pound Riehle testing machine at a speed of 0.231 inch per minute. The ends were supported by curved cast-iron bearing blocks and the load applied at two points (one-third the length of the span from either end) through curved wooden blocks. Deflections were read at the center of the beam to hundredths of an inch by observing on a taut string the movement of a polished metal scale attached to the timber. The method of loading is shown in figure 7, all parts of the testing machine being omitted except the weighing platform.

The 16-foot lodgepole pine beams were tested on a 15-foot span with third-point loading. The arrangement was similar to that used for the caps.

MOISTURE DETERMINATIONS.

A 1-inch section was cut from near the point of failure of each piece tested. This was immediately weighed and later dried to constant weight at the temperature of boiling water. The loss in weight divided by the dry weight, expressed in per cent, is the moisture content of the piece.

GENERAL OBSERVATIONS.

The length, weight, and diameters of the timbers were obtained just before testing. The rings per inch and the proportion of sapwood and of summerwood were obtained from a section cut near the point of failure. The values for the amount of summerwood are approximate, as the summerwood bands were not distinctly marked in many of the pieces.

COMPUTATIONS.

The load and deflection at the elastic limit were obtained from the load-deflection curve, and at maximum load by direct observation.

The fiber stress at the elastic limit and the modulus of rupture were computed for the diameter and moment of inertia obtaining under the smaller loading point, the section being regarded as a true circle. The stiffness factor $\frac{P}{Id}$ was obtained from the moment of inertia (I) and the deflection (d) at the center of the beam. These values for stiffness are comparable for pieces of the same span only. The true modulus of elasticity, which is difficult to obtain accurately for a beam with a varying moment of inertia, depends upon the cube of the span. This relation is not considered in the "stiffness factor" used, $\frac{P}{Id}$, and this causes the values for the 7-foot span to be approximately ten times as large as for the 15-foot span. The work to maximum load was calculated from the area under the load-deflection curve, and is given in terms of unit volume. In the calculations involving the unit stresses of the props, the top area of the prop was used.

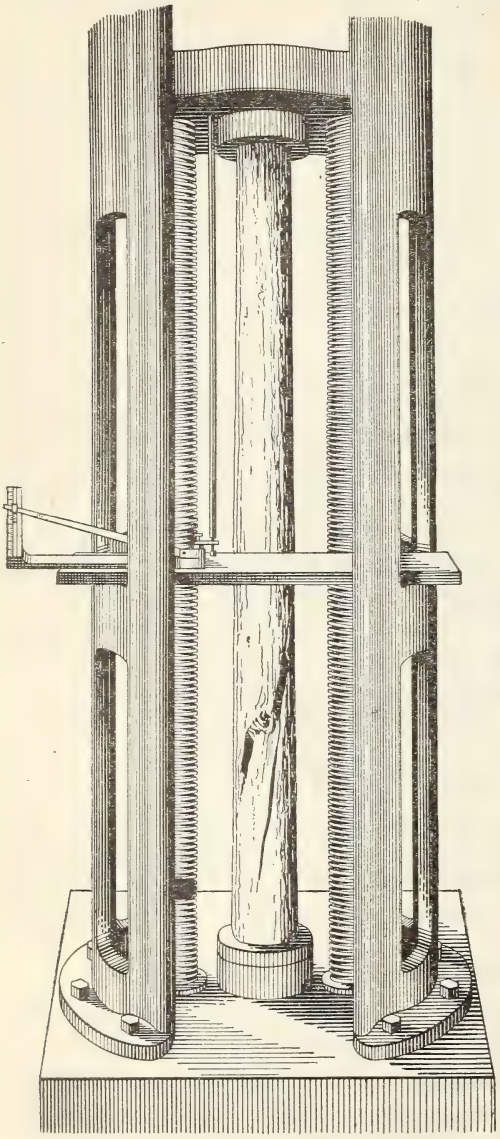


FIG. 6.—Method used in testing mine props in compression.

The volume of the test pieces was calculated by multiplying the average of the areas of the top, the butt, and the mean proportional between them, by the length. The weight per cubic foot was obtained from this estimated volume, and is therefore given as "approximate."

TABLE 11.—*Data on individual crushing tests of green round mine props (nominal size, 5-inch top by 6 feet long).*

Species.	Reference No.	Moisture.	Approximate dry weight (volume as tested).	Rings per inch.	Summerwood.	Sapwood.	Diameter.		Crushing strength at maximum load.	Crushing strength at elastic limit.	Modulus of elasticity.	Remarks.
							Top.	Butt.				
		Per cent.	*Lbs. per cu. ft.*		*Per cent.*	*Per cent.*	*In.*	*In.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*	*1,000 lbs. per sq. in.*	
Lodgepole pine (shipment A).	1	63.4	26.23	47	26	55	5.17	5.33	1,885	1,620	587	Grain slightly spiral.
	2	85.6	22.50	47	20	73	4.93	5.57	1,440	1,049	559	Slightly crooked.
	3	64.0	24.18	40	17	41	6.13	6.37	1,756	1,356	652	Grain slightly spiral.
	4	99.0	22.23	38	16	66	5.65	5.89	1,808	1,595	343	
	5	48.3	24.72	28	15	28	5.89	6.13	2,285	1,981	839	5 knots in failure plane.
	6	65.3	22.79	43	16	50	6.13	6.92	1,835	1,356	582	Unusually knotty.
	7	102.0	21.48	56	20	54	5.57	6.13	1,820	1,396	546	Grain spiral.
	8	83.7	23.46	32	13	62	5.81	6.45	1,745	1,509	560	
	9	67.4	24.22	32	14	65	5.99	6.53	1,800	1,420	602	Do.
	10	78.4	25.70	36	18	46	6.05	6.45	2,281	1,670	719	Do.
Av'ge.	.....	75.7	23.75	40	18	54	5.73	6.18	1,865	1,495	599	
Lodgepole pine (shipment B).	11	61.8	24.57	41	18	50	5.81	6.13	1,712	1,130	539	Slightly crooked.
	12	63.3	23.08	46	22	55	6.05	6.84	1,490	1,250	387	
	13	58.7	26.40	45	20	25	6.13	6.53	1,890	1,559	442	Do.
	14	81.0	22.76	48	20	29	5.65	6.45	1,782	1,354	468	
	15	57.5	19.45	58	13	31	5.25	6.05	1,630	1,292	598	Grain spiral.
	16	82.4	22.86	38	15	58	5.73	6.21	1,705	1,396	621	Do.
	17	108.2	24.38	35	12	73	4.85	6.21	1,169	866	439	
	18	61.8	22.21	44	16	53	5.73	6.37	1,655	1,318	481	
	19	69.6	20.56	31	12	50	6.76	7.42	1,438	891	526	Slightly decayed.
	20	63.7	22.39	48	14	55	7.00	7.56	1,590	1,351	463	Grain spiral.
Av'ge.	.....	70.8	22.86	43	16	48	5.90	6.58	1,605	1,240	496	
Alpine fir...	1	58.5	19.44	23	12	.....	5.17	6.05	1,770	1,334	463	
	2	38.6	24.07	42	15	.....	5.37	5.73	2,355	1,944	706	
	3	119.9	20.03	32	18	.....	4.70	5.38	1,712	1,441	502	
	4	115.3	.....	28	22	.....	4.90	5.58	1,573	1,378	401	Grain slightly spiral.
	5	86.3	22.41	25	20	.....	5.00	5.50	1,930	1,630	547	Do.
	6	78.1	20.28	13	14	.....	4.77	5.65	1,870	1,568	519	
	7	123.6	21.58	23	16	.....	4.85	5.41	1,978	1,300	633	
	8	63.1	22.82	20	10	.....	4.70	5.65	2,007	1,268	486	
	9	135.7	20.22	29	9	.....	4.62	5.57	2,082	1,551	614	
Av'ge.	.....	91.0	21.36	26	15	.....	4.90	5.65	1,920	1,490	541	
Engelmann spruce.	1	52.4	23.32	32	13	.....	5.65	7.08	2,040	1,755	642	
	2	68.8	24.14	46	18	.....	6.20	7.00	2,000	1,459	686	
	3	53.1	24.08	38	14	.....	5.25	5.73	1,875	1,293	578	
	4	75.4	22.98	25	16	.....	4.38	5.41	1,511	1,062	358	
	5	89.1	22.82	25	20	.....	4.46	5.16	1,515	1,280	459	
	6	73.2	24.20	19	14	.....	4.14	5.09	1,590	1,340	592	Crooked.
	7	72.2	22.96	26	15	.....	4.77	5.41	1,663	1,230	518	Grain spiral.
	8	53.8	25.46	28	16	.....	4.62	5.25	1,536	1,192	422	Crooked.
	9	55.8	23.79	42	14	.....	4.93	5.41	1,888	1,362	538	
	10	53.3	27.38	46	20	.....	4.38	5.49	2,115	1,725	608	Grain slightly spiral.
	11	38.1	23.66	24	14	.....	5.65	6.76	1,518	1,115	416	Crooked.
Av'ge.	.....	62.3	24.07	32	16	.....	4.95	5.80	1,750	1,347	529	
Douglas fir..	1	89.1	27.34	20	26	68	4.95	5.45	2,622	2,180	799	
	2	34.9	25.22	40	24	14	5.33	5.81	2,870	2,242	596	
	3	91.6	24.29	23	22	52	5.41	6.05	2,715	2,438	765	
	4	66.9	25.33	38	14	42	5.60	6.30	2,200	1,946	718	Grain spiral.
	5	37.8	28.57	61	24	19	4.93	5.73	2,358	1,885	676	Do.
	6	38.2	27.08	40	28	26	6.84	7.16	2,664	2,176	856	
	7	42.9	27.52	45	23	31	5.73	6.45	2,730	2,330	796	Do.
	8	34.8	31.84	26	17	38	5.01	5.57	2,560	2,030	718	
	9	30.0	30.10	76	25	12	5.89	6.61	2,545	1,908	789	Do.
	10	38.5	27.77	17	28	70	5.09	5.41	2,560	2,160	865	Do.
Av'ge.	.....	50.5	27.50	39	23	37	5.48	6.05	2,580	2,130	758	

TABLE 11.—*Data on individual crushing tests of green round mine props (nominal size, 5-inch top by 6 feet long)*—Continued.

Species.	Reference No.	Moisture.	Approximate dry weight (volume as tested).	Rings per inch.	Summerwood.	Sapwood.	Diameter.		Crushing strength at maximum load.	Crushing strength at elastic limit.	Modulus of elasticity.	Remarks.
							Top.	Butt.				
		Per cent.	*Lbs. per cu. ft.*		*Per cent.*	*Per cent.*	*In.*	*In.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*	*1,000 lbs. per sq. in.*	
Bristle-cone pine.	1	86.7	30.78	34	22	56	4.25	5.13	1,474	1,128	390	Crooked.
	2	109.0	26.83	32	19	56	4.65	5.50	2,026	1,590	638	
	3	74.9	30.86	33	18	39	4.80	5.50	1,364	1,050	453	
	4	106.1	26.17	41	21	36	5.33	6.40	1,690	1,435	505	
	5	94.5	29.57	31	22	47	4.52	4.91	1,480	1,185	525	
	6	56.1	25.68	31	24	.....	3.98	4.77	1,400	965	446	Crooked and unusually knotty.
	7	60.3	28.95	38	16	51	4.46	5.17	1,760	1,408	574	Do.
	8	85.1	25.83	43	23	46	5.17	6.05	1,828	1,430	464	Grain slightly spiral.
	9	101.0	25.72	32	16	43	4.38	5.16	1,941	1,528	571	
	10	85.5	26.39	39	16	38	4.30	5.17	1,610	1,378	516	
Av'ge.	.....	85.9	27.68	35	20	46	4.58	5.38	1,657	1,310	508	
Western yellow pine (shipment A.)	1	91.8	22.67	14	14	.....	4.25	5.25	1,355	1,128	428	Do.
	2	97.7	23.09	16	19	.....	4.25	5.00	1,630	1,410	516	
	3	88.9	22.52	13	14	.....	4.35	5.10	1,443	1,211	345	
	4	92.0	23.55	14	14	.....	4.70	5.40	1,269	1,038	451	Crooked.
	5	83.2	22.48	13	15	.....	4.65	5.60	1,322	1,060	402	Do.
	6	104.5	22.33	13	12	.....	4.30	5.13	1,481	1,172	475	Do.
	7	101.2	22.71	14	16	.....	4.78	5.16	1,518	1,119	438	
	8	96.6	23.62	15	15	.....	4.38	5.41	1,522	1,262	448	
	9	89.3	25.70	15	13	.....	4.14	4.94	1,681	1,412	512	Grain slightly spiral.
	10	116.1	.....	13	15	.....	4.62	5.01	1,512	1,193	416	Do.
Av'ge.	.....	96.1	23.18	14	15	.....	4.44	5.20	1,475	1,201	443	
Western yellow pine (shipment B.)	11	81.1	25.68	32	14	.....	5.25	6.15	2,000	1,570	611	Unusually knotty.
	12	90.5	23.22	11	14	.....	5.01	5.73	1,726	1,320	457	Grain slightly spiral.
	13	83.0	24.80	24	20	.....	5.65	6.13	1,668	1,275	448	Do.
	14	113.2	.....	19	23	.....	5.33	6.17	2,055	1,435	491	
	15	54.8	25.92	19	17	.....	5.49	6.05	1,682	1,352	478	Grain spiral, crooked.
	16	63.5	21.58	16	13	.....	5.41	6.05	1,670	1,132	532	
	17	78.8	24.62	16	15	.....	5.33	5.97	2,410	1,883	702	
	18	105.5	24.78	16	12	.....	5.49	5.81	1,950	1,269	458	
	19	76.6	26.20	16	14	.....	5.41	6.05	2,005	1,392	569	
	20	72.8	26.28	14	13	.....	5.09	5.89	2,225	1,865	762	
Av'ge.	.....	82.0	24.78	18	16	.....	5.35	6.00	1,940	1,450	561	

TABLE 12.—*Data on individual crushing tests of air-seasoned round mine props (nominal size, 5-inch top by 6 feet long).*

Species.	Reference No.	Moisture.	Approximate dry weight (volume as tested).	Rings per inch.	Summerwood.	Sapwood.	Diameter.		Crushing strength at maximum load.	Crushing strength at elastic limit.	Modulus of elasticity.	Remarks.
							Top.	Butt.				
		Per cent.	*Lbs. per cu. ft.*		*Per cent.*	*Per cent.*	*In.*	*In.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*	*1,000 lbs. per sq. in.*	
Lodgepole pine (shipment A).	1	11.5	24.58	51	21	55	4.85	5.17	3,910	3,465	890	Grain spiral.
	2	11.4	24.46	43	22	58	4.77	5.57	3,992	3,580	875	Do.
	3	11.2	27.96	57	18	33	5.17	5.57	4,770	4,190	1,194	Do.
	4	12.3	24.16	34	20	68	5.09	5.57	3,340	2,750	954	Do.
	5	11.0	25.83	47	19	35	4.77	5.25	4,640	3,580	1,031	Do.
Av'ge.	.....	11.5	25.40	46	20	50	4.93	5.43	4,130	3,513	993	
Lodgepole pine (shipment B).	6	11.0	28.14	43	26	42	4.38	5.01	5,100	4,110	1,198	Do.
	7	12.0	27.72	45	26	.....	5.25	5.57	6,340	4,980	1,450	
	8	15.9	23.42	50	26	61	5.17	5.49	4,980	4,010	1,135	Do.
	9	11.2	29.52	45	20	37	4.01	5.73	6,190	4,750	1,452	Do.
	10	11.1	26.58	42	17	37	5.25	5.41	5,230	4,240	1,175	Do.
Av'ge.	.....	12.2	27.08	45	23	44	4.81	5.44	5,568	4,438	1,282	
Alpine fir	1	12.4	20.24	15	16	.....	4.30	5.41	4,120	3,165	890	
	2	12.0	22.88	23	12	.....	4.46	5.33	4,260	3,875	1,043	
	3	10.5	20.38	16	9	.....	4.06	5.09	3,910	3,550	1,002	Do.
Av'ge.	.....	11.6	21.17	18	12	.....	4.27	5.28	4,097	3,530	978	
Engelmann spruce.	1	11.7	27.42	41	23	.....	4.62	5.97	5,560	4,290	1,321	Do.
	2	11.2	28.10	25	13	.....	5.09	5.49	3,280	2,555	802	Do.
	3	11.0	23.33	29	13	.....	3.50	4.62	3,742	3,120	1,021	Do.
	4	13.0	24.00	43	22	.....	3.98	5.25	2,990	2,410	703	Crooked.
	5	13.7	24.81	50	28	.....	4.30	4.93	4,540	3,850	1,196	Grain spiral.
	6	11.3	23.86	31	20	.....	4.62	5.33	4,710	3,822	1,150	
	7	10.9	21.78	16	12	.....	4.85	5.49	4,030	3,030	1,098	
Av'ge.	.....	11.8	24.76	33	19	.....	4.42	5.29	4,122	3,297	1,042	
Douglas fir	1	11.9	31.63	76	25	31	4.30	4.62	2,960	2,340	873	Crooked; grain spiral.
	2	11.5	32.66	47	25	39	4.54	5.39	5,250	4,450	1,322	Crooked; grain unusually knotty.
	3	11.6	28.98	65	28	39	4.85	5.17	4,580	3,465	986	Crooked; grain spiral.
	4	13.7	28.31	30	26	60	5.25	5.41	5,720	4,240	1,324	Grain slightly spiral, knotty.
	5	13.0	26.06	28	21	37	5.33	6.05	4,660	3,590	1,151	
Av'ge.	.....	12.3	29.53	49	25	41	4.85	5.33	4,634	3,617	1,131	
Bristle-cone pine.	1	12.5	29.38	40	22	42	3.90	4.54	4,320	3,512	1,023	
	2	12.6	32.01	45	19	49	3.66	4.30	4,390	3,420	862	
	3	12.4	36.46	42	20	.....	3.66	4.22	3,042	2,280	837	Crooked; grain spiral.
	4	12.2	30.34	35	19	68	3.18	4.30	2,340	2,013	628	Crooked.
	5	12.2	25.37	30	20	.....	3.98	4.85	3,415	2,890	779	
Av'ge.	.....	12.4	30.71	38	20	.....	3.68	4.44	3,501	2,823	826	
Western yellow pine (shipment A).	1	10.5	21.48	16	17	21	3.66	4.80	3,050	2,470	742	
	2	11.1	23.55	15	18	88	4.30	4.62	3,842	3,310	852	Grain spiral.
	3	11.9	21.99	14	13	95	4.06	4.85	3,230	3,625	1,068	
	4	11.6	25.50	11	19	96	3.50	4.80	5,330	4,780	1,146	
	5	13.4	23.69	15	12	.....	4.14	4.85	3,370	2,822	626	
Av'ge.	.....	11.7	23.24	14	16	75	3.93	4.78	3,764	3,401	887	
Western yellow pine (shipment B).	6	11.7	26.30	17	12	.....	4.93	5.57	4,070	3,250	976	Crooked.
	7	11.6	24.03	19	17	.....	4.70	5.25	4,260	3,690	863	Grain spiral.
	8	13.0	27.72	31	20	.....	4.93	5.65	4,420	3,350	1,160	
	9	11.5	25.73	13	19	.....	4.93	5.41	4,790	3,770	1,115	Do.
	10	10.9	23.64	12	14	.....	4.62	5.33	3,120	2,270	628	Grain spiral, crooked.
Av'ge.	.....	11.7	25.48	18	16	.....	4.82	5.44	4,132	3,266	956	

TABLE 13.—*Data on individual bending tests of green round mine caps (nominal size, 5-inch top by 8 feet long; span, 7 feet; third-point loading).*

Species.	Reference number.	Moisture.	Approximate dry weight (volume as tested).	Rings per inch.	Summerwood.	Sapwood.	Diameter.		Modulus of rupture.	Fiber stress at elastic limit.	Stiffness factor $\left(\frac{P}{ld}\right)$	Manner of failure.[1]	Remarks.
							Top.	Butt.					
		Per cent.	*Lbs. per cu. ft.*		*Per cent.*	*Per cent.*	*Inches.*	*Inches.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*			
Lodgepole pine (shipment A)	1	63.4	24.62	61	14	10	5.17	5.60	4,550	2,702	80.0	C.	
	2	77.3	25.44	44	11	49	5.63	6.00	4,040	3,830	88.0	T.	
	3	56.7	24.52	23	17	33	5.75	6.25	5,840	3,190	112.5	C.	
	4	66.1	24.03	40	23	58	5.42	6.38	4,620	2,635	95.2	C.	
	5	106.1	22.96	42	18	60	5.25	6.13	4,430	2,810	72.1	C.	
	6	97.5	21.07	44	23	60	5.75	6.50	4,830	3,315	85.5	T.	
	7	62.9	24.72	41	21	55	5.67	6.30	5,720	2,965	119.7	C.	Grain slightly spiral.
	8	129.8	24.23	56	22	77	5.60	6.12	6,460	3,250	115.4	C.	
	9	133.3	23.96	46	18	77	5.75	6.00	5,330	3,615	107.1	C.	
	10	100.0	23.24	30	18	64	5.90	6.68	5,900	2,725	104.5	C.	
Average		89.3	23.88	43	19	54	5.59	6.20	5,172	3,104	08.9		
Lodgepole pine (shipment B)	11	63.5	25.20	46	8	31	5.38	6.00	4,410	2,865	88.4	C.	
	12	40.1	26.31	36	10	37	5.95	6.70	5,900	3,555	124.4	C.	
	13	89.5	22.78	43	18	43	5.97	6.75	4,230	2,690	70.2	C.	
	14	64.8	25.51	52	18	50	5.75	6.00	6,180	3,330	126.2	C.	
	15	63.8	23.06	40	18	29	6.00	6.63	4,690	2,595	77.3	C.	Grain spiral.
	16	49.3	24.87	52	21	16	5.88	6.50	5,160	3,250	77.2	C.	
	17	62.6	24.09	43	22	54	6.00	6.75	5,340	2,215	92.5	C.	Do.
	18	48.0	20.89	31	12	54	5.75	6.63	3,585	2,295	55.3	T.	
	19	82.7	22.12	47	15	72	5.25	6.00	4,470	2,730	85.3	C.	Do.
	20	41.2	22.80	38	20	14	5.88	6.50	3,710	2,090	63.1	T.	
Average		60.6	23.76	43	15	40	5.78	6.45	4,768	2,762	86.0		
Alpine fir	1	57.6	20.88	36	22	.....	4.80	5.50	5,260	2,165	108.8	C.	Grain slightly spiral.
	2	68.1	20.38	19	14	.....	5.63	6.50	3,030	2,150	82.5	T.	Do.
	3	109.8	21.54	34	13	.....	5.00	5.88	4,880	2,802	89.6	C.	
	4	76.8	19.72	18	12	.....	4.30	5.80	5,020	2,810	87.1	T.	
	5	90.7	20.79	23	16	.....	4.50	5.50	4,270	2,910	73.1	T.	
	6	147.2	18.36	8	17	.....	4.13	5.50	1,945	1,782	57.6	T.	
	7	146.1	16.57	9	17	.....	4.40	5.58	4,160	1,970	70.9	T.	
	8	107.1	19.88	22	18	.....	4.75	5.75	4,260	2,710	72.6	T.	
	9	92.3	17.94	20	14	.....	4.38	5.38	4,310	2,755	71.2	T.	
Average		99.5	19.56	21	16	.....	4.65	5.72	4,139	2,450	79.3		

Engelmann spruce	1	36.3	26.42	23	26	.....	5.05	6.30	7,280	3,450	130.5	C. Do.
	2	43.2	25.02	24	17	.....	5.75	7.00	5,450	3,665	99.8	C.
	3	44.2	23.16	36	20	.....	5.42	6.60	5,300	2,740	114.2	C.
	4	54.6	23.12	23	11	.....	5.25	6.38	5,430	2,750	81.5	C.
	5	69.2	23.01	25	10	.....	4.88	6.25	4,560	2,515	68.2	C.
	6	58.4	24.53	24	14	.....	4.44	5.92	5,570	2,653	89.6	C. Do.
	7	74.4	20.41	38	30	.....	4.75	5.88	5,620	1,991	86.5	C.
	8	47.2	24.98	43	23	.....	5.08	5.95	5,980	2,630	120.0	C.
	9	56.3	23.45	45	21	.....	5.38	6.25	4,890	2,315	68.4	C.
	10	38.3	27.61	30	19	.....	4.85	6.95	5,411	2,815	84.8	C.
	11	74.6	21.87	17	24	.....	6.00	6.88	3,500	2,270	101.5	T.
Average	.....	54.3	23.96	30	20	.....	5.16	6.40	5,308	2,709	95.0	
Douglas fir	1	101.5	26.18	16	11	67	4.00	5.00	6,230	3,500	88.0	C.
	2	65.3	31.52	22	24	54	6.25	7.00	7,310	3,490	106.0	T.
	3	56.4	29.36	25	20	34	5.00	5.62	6,940	3,200	106.8	T.
	4	119.1	25.23	22	24	69	4.88	5.25	6,620	3,820	107.9	C.
	5	34.6	24.38	33	14	71	4.63	5.38	6,150	3,220	76.7	T.
	6	32.6	24.68	38	16	16	5.08	5.42	6,470	4,110	100.4	T.
	7	35.3	27.44	33	31	18	5.25	5.75	7,170	2,535	107.2	T.
	8	97.8	24.76	25	19	58	4.13	5.38	4,840	2,505	55.0	C.
	9	72.9	25.83	28	27	56	4.25	5.00	6,890	4,675	96.8	T.
	10	78.1	25.43	24	22	53	4.30	6.75	7,060	3,490	86.8	T.
Average	.....	69.4	26.48	27	22	50	4.78	5.66	6,568	3,455	85.2	
Bristle-cone pine	1	70.3	30.53	33	17	26	5.63	7.00	5,480	2,395	63.2	C.
	2	96.1	28.50	35	16	74	5.50	6.40	4,610	1,785	65.3	C.
	3	86.8	30.34	62	18	35	3.38	4.00	4,950	3,960	57.6	C.
	4	76.9	32.29	29	17	74	3.58	4.75	3,970	1,975	48.3	C.
	5	90.1	23.71	27	12	12	4.50	5.38	4,541	2,151	85.7	C.
	6	66.2	24.23	41	10	.....	4.78	6.05	3,735	2,050	52.6	C.
	7	84.9	28.38	25	9	67	4.25	5.25	5,190	2,705	81.2	C.
	8	88.8	27.13	35	12	60	5.13	5.88	5,210	3,115	76.3	C.
	9	81.3	25.13	39	18	69	5.13	6.00	4,590	2,790	85.6	C.
	10	81.7	24.46	42	12	58	4.38	5.50	3,500	1,666	50.4	T.
Average	.....	74.3	27.47	37	14	53	4.63	5.62	4,578	2,459	66.6	

[1] C indicates compression failure; T, tension failure.

TABLE 13.—*Data on individual bending tests of green round mine caps (nominal size, 5-inch top by 8 feet long; span, 7 feet; third-point loading)*—Continued.

Species.	Reference number.	Moisture.	Approximate dry weight (volume as tested).	Rings per inch.	Summerwood.	Sapwood.	Diameter.		Modulus of rupture.	Fiber stress at elastic limit.	Stiffness factor $\left(\frac{P}{ld}\right)$	Manner of failure.[1]	Remarks.
							Top.	Butt.					
		Per cent.	*Lbs. per cu. ft.*		*Per cent.*	*Per cent.*	*Inches.*	*Inches.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*			
Western yellow pine (shipment A)	1	83.3	19.42	12	14	.....	4.75	6.10	3,980	1,889	77.7	C.	
	2	89.5	21.30	12	14	.....	4.75	5.75	4,260	1,887	78.5	C.	
	3	88.8	21.58	13	16	19	4.38	5.70	4,960	2,695	84.8	T.	
	4	83.3	20.93	13	13	92	4.25	5.82	4,050	2,114	61.8	C.	
	5	71.1	23.90	13	14	89	4.63	5.38	4,880	2,775	86.9	C.	
	6	105.6	22.83	15	19	93	3.88	4.75	4,260	2,205	71.1	C.	
	7	106.3	18.41	14	10	98	4.50	6.25	3,880	1,719	63.4	C.	
	8	73.4	21.20	14	11	94	4.20	5.42	4,530	2,095	82.3	C.	
	9	104.0	19.94	12	15	.....	4.80	5.85	3,860	1,553	59.1	C.	
	10	79.7	19.72	14	17	.....	3.75	5.00	4,670	2,765	79.6	C.	
Average	.....	88.5	20.92	13	14	.....	4.39	5.60	4,333	2,170	74.5		
Western yellow pine (shipment B)	11	179.5	21.22	15	20	17	4.50	5.25	4,280	2,175	77.1	C.	
	12	143.9	22.01	30	13	.....	4.25	5.00	4,640	2,560	83.6	C.	
	13	155.2	23.68	22	12	92	4.63	5.50	6,190	3,500	87.1	C.	
	14	198.4	19.95	19	16	.....	3.62	5.25	5,150	3,025	66.2	C.	
	15	105.3	22.18	33	17	28	4.88	6.00	4,620	3,055	61.3	C.	
	16	86.5	22.78	42	22	28	4.38	6.12	3,320	2,148	35.9	T.	
	17	178.0	22.10	33	29	23	4.25	5.00	5,380	3,540	75.7	C.	
	18	140.7	23.48	15	10	.....	5.00	5.88	5,500	3,210	79.4	C.	
	19	113.5	24.03	34	14	27	4.50	5.50	4,980	3,165	89.8	C.	
	20	169.5	20.62	16	16	25	4.20	5.00	4,910	2,520	70.1	C.	
Average	.....	147.1	22.20	26	17	.....	4.42	5.45	4,897	2,890	72.6		

[1] C indicates compression failure; T, tension failure.

TABLE 14.—*Data on individual bending tests of air-seasoned round mine caps (nominal size, 5-inch top by 8 feet long; span, 7 feet; third-point loading).*

Species.	Reference number.	Moisture.	Approximate dry weight (volume as tested).	Rings per inch.	Summerwood.	Sapwood.	Diameter.		Modulus of rupture.	Fiber stress at elastic limit.	Stiffness factor $\left(\frac{P}{ld}\right)$	Manner of failure.[1]	Remarks.
							Top.	Butt.					
		Per cent.	*Lbs. per cu. ft.*		*Per cent.*	*Per cent.*	*Inches.*	*Inches.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*			
Lodgepole pine (shipment A)	1	11.9	26.22	61	18	39	4.62	5.09	8,240	6,080	119.5	T.	
	2	11.3	26.17	33	10	37	4.54	5.09	9,440	7,170	138.2	C. T.	Grain spiral.
	3	10.6	26.97	60	16	61	4.85	5.49	11,630	8,640	152.2	C. T.	
	4	11.5	25.07	44	17	29	4.70	5.33	7,180	4,790	129.7	T.	Do.
	5	11.5	26.51	72	24	47	5.09	5.17	8,640	6,360	126.0	T.	Crooked.
Average		11.4	26.18	54	17	43	4.76	5.21	9,026	6,600	133.1		
Lodgepole pine (shipment B)	6	10.9	21.92	42	18	77	4.62	5.41	7,980	6,700	98.2	T.	
	7	10.8	21.16	42	12	40	4.54	5.57	4,490	4,230	84.1	T.	
	8	11.7	27.02	44	16	38	5.41	5.73	9,620	7,290	148.2	T.	
	9	10.6	25.78	43	16	50	4.62	5.33	7,270	6,370	138.7	T.	
	10	11.4	23.57	47	17	.....	5.01	5.41	5,410	5,220	103.2	T.	Grain spiral.
Average		11.1	23.89	44	16	51	4.84	5.49	6,954	5,962	114.2		
Alpine fir	1	10.4	21.33	29	12	.....	4.62	5.25	8,790	6,600	125.2	T.	
	2	11.4	20.46	22	9	.....	4.54	5.57	6,770	4,320	124.0	T.	
	3	11.4	20.17	20	19	.....	3.66	5.25	5,270	4,940	85.2	T.	Unusually knotty.
	4	12.1	22.32	37	15	.....	3.98	5.09	6,520	4,840	85.8	T.	Grain spiral.
	5	11.6	23.08	24	14	.....	4.30	5.25	9,350	6,600	122.1	T.	
Average		11.4	21.47	26	14	.....	4.22	5.28	7,340	5,460	108.5		
Englemann spruce	1	11.7	22.52	44	20	.....	5.33	6.05	6,260	5,190	103.5	T.	
	2	11.8	27.50	45	20	.....	5.09	5.25	9,380	6,950	137.5	T.	
	3	11.5	27.49	37	18	.....	3.98	5.17	9,900	7,340	128.2	C. T.	
	4	10.6	26.02	27	9	.....	3.50	4.62	9,300	7,280	151.2	T.	
	5	8.8	23.67	34	20	.....	4.14	5.65	6,370	6,330	72.0	T.	
Average		10.9	25.44	37	17	.....	4.41	5.35	8,242	6,618	118.5		

[1] C indicates compression failure; T, tension failure.

TABLE 14.—*Data on individual bending tests of air-seasoned round mine caps (nominal size, 5-inch top by 8 feet long; span, 7 feet; third-point loading)*—Continued.

Species.	Reference number.	Moisture.	Approximate dry weight (volume as tested).	Rings per inch.	Summerwood.	Sapwood.	Diameter.		Modulus of rupture.	Fiber stress at elastic limit.	Stiffness factor $\left(\frac{P}{ld}\right)$	Manner of failure.[1]	Remarks.
							Top.	Butt.					
		Per cent.	*Lbs. per cu. ft.*		*Per cent.*	*Per cent.*	*Inches.*	*Inches.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*			
Douglas fir	1	11.4	27.87	22	28	64	4.30	5.17	10,680	6,970	121.8	T.	
	2	12.3	29.48	29	23	54	4.77	5.41	10,030	7,180	145.1	T.	Grain spiral.
	3	11.6	26.31	15	14	74	4.62	5.57	10,960	7,300	129.3	C. T.	Do.
	4	12.2	26.59	25	22	46	3.82	5.09	5,790	5,100	92.3	T.	
	5	11.5	29.36	26	21	44	3.98	4.77	8,700	7,660	142.5	T.	Do.
Average		11.8	27.92	23	22	56	4.30	5.20	9,232	6,842	126.3		
Bristle-cone pine	1	12.5	26.43	52	14	38	4.22	5.09	9,210	5,420	103.8	T.	Grain spiral, unusually knotty.
	2	10.7	29.31	32	.....	55	3.66	4.54	7,320	6,700	116.1	T.	
	3	10.9	32.63	33	15	63	3.82	5.09	8,960	5,800	90.0	T.	Grain spiral.
	4	12.0	32.32	40	10	62	3.90	5.25	7,000	4,120	89.3	T.	Crooked.
	5	11.6	31.63	27	18	74	3.50	4.93	9,550	6,380	89.5	C. T.	
Average		11.5	30.46	37	14	58	3.82	4.98	8,408	5,684	97.7		
Western yellow pine (shipment A)	1	10.5	22.62	14	11	93	3.66	5.09	7,280	6,020	96.3	T.	
	2	10.5	24.93	15	13	.....	3.58	4.77	8,530	6,380	115.7	T.	
	3	10.6	24.65	15	12	.....	3.65	4.70	9,770	7,730	118.2	T.	
	4	10.4	21.28	13	10	.....	3.50	5.09	7,060	4,850	87.5	C. T.	
	5	9.4	22.22	15	12	.....	3.50	4.62	5,660	3,870	101.5	T.	Grain spiral.
Average		10.3	23.14	14	12	.....	3.58	4.85	7,660	5,770	103.8		
Western yellow pine (shipment B)	6	11.4	25.63	26	8	93	3.82	5.25	6,330	5,830	76.8	T.	
	7	10.4	24.54	21	17	95	3.90	5.33	4,210	4,220	75.0	T.	
	8	10.8	24.77	17	20	.....	4.22	5.41	5,380	4,600	62.2	T.	Crooked.
	9	10.5	24.46	23	11	97	3.58	4.62	6,780	5,470	112.6	T.	Unusually knotty.
	10	10.3	22.66	18	17	.....	3.98	5.01	7,360	4,570	73.5	T.	
Average		10.7	24.41	21	15	.....	3.90	5.12	6,012	4,938	80.0		

[1] C indicates compression failure; T, tension failure.

TABLE 15.—*Data on individual bending tests of green round beams (16 feet long; span, 15 feet; third-poin t loading).*

Species and size.	Ref. No.	Moisture.	Approximate dry weight (volume as tested).	Rings per inch.	Summerwood.	Sapwood.	Diameter.		Modulus of rupture.	Fiber stress at elastic limit.	Stiffness factor $\left(\frac{P}{ld}\right)$	Work to maximum load.	Manner of failure.[1]	Remarks.
							Top.	Butt.						
		Per cent.	*Lbs. per cu. ft.*		*Per cent.*	*Per cent.*	*Inches.*	*Inches.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*		*Inch lbs. per cu. in.*		
Lodgepole pine cut from live timber:														
8-inch butt	1	84.0	21.96	37	18	.....	6.53	7.76	5,190	2,425	11.71	3.0	C.	
	2	66.5	20.03	34	18	50	6.61	8.13	5,060	3,140	10.65	6.3	C.	
	3	80.6	23.32	28	14	47	7.24	8.44	5,210	2,770	10.10	4.4	C.	
	4	77.7	23.23	31	18	55	6.84	8.28	5,040	2,895	10.71	5.0	C.	
	5	89.2	24.44	29	23	49	7.32	8.59	5,770	3,315	13.42	6.6	C. T.	
	6	99.4	24.04	32	14	65	6.76	8.75	5,510	4,200	12.01	2.6	C. T.	
	7	75.5	24.56	33	15	59	6.53	8.04	4,860	2,581	9.26	4.8	C. T.	
	8	66.1	23.71	31	14	43	6.92	8.20	5,270	3,135	11.10	4.8	C.	Grain spiral.
	9	62.1	23.53	35	22	41	6.68	7.88	4,860	3,010	10.42	5.1	C.	Do.
	10	71.2	25.18	33	21	.....	6.29	7.96	6,210	3,730	10.50	4.7	C.	
Average	.....	77.3	23.40	32	18	51	6.77	8.20	5,348	3,120	10.99	4.7		
10-inch butt	11	95.7	23.78	25	16	44	8.20	9.71	4,510	2,870	9.70	5.3	C. T.	
	12	113.0	23.28	26	21	71	8.44	9.47	5,020	3,205	11.36	3.2	C. T.	
	13	97.5	25.63	24	19	.....	8.59	10.03	5,810	3,905	11.73	4.9	C.	Grain spiral.
	14	73.4	22.38	32	13	.....	7.24	9.39	4,900	2,038	7.48	3.8	C.	
	15	82.2	22.58	28	16	46	8.44	10.27	4,980	2,770	10.38	5.2	C.	
	16	88.5	22.78	31	21	51	7.72	9.87	5,380	3,170	9.87	6.4	C.	
	17	94.5	23.15	26	21	.....	9.63	10.74	4,640	2,320	10.72	6.0	C.	
	18	73.8	23.48	26	17	59	7.88	9.95	6,230	3,510	10.96	7.7	C.	
	19	87.2	24.19	28	21	56	8.04	9.71	5,590	3,395	9.46	4.3	C. T.	
	20	118.2	21.44	21	21	79	8.44	10.51	5,270	2,900	11.52	7.8	C.	
Average	.....	90.2	23.27	27	19	58	8.26	9.97	5,233	3,008	10.32	5.5		
12-inch butt	21	99.1	22.44	18	22	67	10.82	12.09	6,270	3,750	9.81	6.2	C. T.	
	22	99.6	21.63	23	27	71	10.11	11.85	5,790	3,780	13.70	5.4	C.	
	23	96.0	23.62	22	19	65	10.03	11.46	5,070	2,592	8.16	5.6	C.	Crooked and unusually knotty.
	24	81.6	27.56	24	21	.....	9.39	10.98	5,650	2,650	11.48	6.1	C.	
	25	96.3	22.53	24	13	65	9.87	11.46	4,440	2,298	8.84	7.0	C.	Grain spiral.
	26	98.2	20.06	23	24	52	10.11	11.30	4,730	2,970	10.06	6.6	C.	
	27	94.0	21.35	24	17	.....	9.23	11.85	4,880	3,438	11.42	3.1	C. T.	
	28	78.3	20.23	23	11	47	9.39	11.54	4,230	2,560	9.05	2.0	C. T.	Do.
	29	82.5	24.09	24	17	38	9.39	11.30	4,820	2,890	10.13	6.1	C.	Do.
	30	92.5	22.12	23	16	65	9.87	12.41	5,070	2,940	9.60	4.4	C. T.	
Average	.....	91.8	22.56	23	19	59	9.82	11.62	5,095	2,987	10.23	5.2		

[1] C indicates compression failure; T, tension failure.

TABLE 15.—*Data on individual bending tests of green round beams (16 feet long; span, 15 feet; third-point loading)*—Continued.

Species and size.	Ref. No.	Moisture.	Approximate dry weight (volume as tested).	Rings per inch.	Summerwood.	Sapwood.	Diameter.		Modulus of rupture.	Fiber stress at elastic limit.	Stiffness factor $\left(\frac{P}{ld}\right)$	Work to maximum load.	Manner of failure.[1]	Remarks.
							Top.	Butt.						
Lodgepole pine (fire killed) water soaked, cut from timber after standing dead for 30 years:		*Per cent.*	*Lbs. per cu. ft.*		*Per cent.*	*Per cent.*	*Inches.*	*Inches.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*		*Inch lbs. per cu. in.*		
8-inch butt	1	39.0	24.67	48	21	30	6.92	9.06	5,770	3,690	9.48	4.4	T.	Grain spiral.
	2	35.0	26.72	48	17	28	7.08	8.83	5,560	2,670	8.90	4.9	T.	Do.
	3	45.2	25.49	52	16	21	6.92	8.28	3,570	2,210	8.00	2.8	C.	Do.
	4	35.0	27.38	34	17	26	7.00	8.52	6,580	2,935	13.25	7.6	C. T.	
	5	36.2	25.82	40	18	43	7.08	7.80	5,760	3,020	12.28	6.8	C.	
Average	.....	38.1	26.02	44	18	30	7.00	8.50	5,448	2,905	10.38	5.3		
10-inch butt	6	31.4	27.61	48	22	19	7.56	9.88	6,500	4,180	10.97	5.4	C. T.	Do.
	7	45.9	21.62	42	20	.....	8.12	10.19	5,020	2,805	10.62	3.7	C. T.	Do.
	8	45.5	22.70	36	19	31	8.36	10.27	3,870	1,592	7.09	4.0	C. T.	Do.
	9	29.8	24.65	37	14	.....	7.80	9.71	4,560	2,585	7.38	2.4	C. T.	
	10	47.7	23.67	35	20	36	9.23	11.14	4,750	3,590	8.13	1.6	C.	
Average	.....	40.1	24.05	40	20	.....	8.21	10.24	4,940	2,950	8.84	3.4		
12-inch butt	11	27.8	25.32	24	20	.....	10.11	12.01	3,925	1,862	6.36	3.3	T.	
	12	41.7	23.23	27	15	20	10.11	12.89	4,497	2,605	9.18	2.0	T.	Do.
	13	38.9	22.32	29	16	15	10.98	12.97	4,230	2,345	8.13	2.8	T.	
	14	36.3	26.13	26	17	25	9.47	11.77	5,680	2,960	9.71	8.2	C. T.	
	15	41.2	23.33	34	13	19	9.31	12.73	3,820	1,828	5.18	5.3	C.	
Average	.....	37.2	24.06	28	16	20	10.00	12.47	4,430	2,320	7.71	4.3		

[1] C indicates compression failure; T, tension failure.

TABLE 16.—*Data on individual bending tests of air-seasoned round beams (16 feet long; span, 15 feet; third-point loading).*

Species and size.	Ref. No.	Moisture.	Approximate dry weight (volume as tested).	Rings per inch.	Summerwood.	Sapwood.	Diameter.		Modulus of rupture.	Fiber stress at elastic limit.	Stiffness factor $\left(\frac{P}{fd}\right)$	Work to maximum load.	Manner of failure.[1]	Remarks.
							Top.	Butt.						
		Per cent.	*Lbs. per cu. ft.*		*Per cent.*	*Per cent.*	*Inches.*	*Inches.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*		*Inch lbs. per cu. in.*		
Lodgepole pine cut from live timber:														
8-inch butt	1	17.0	28.46	29	19	50	7.64	8.36	7,840	4,640	14.24	4.9	C. T.	Grain spiral.
	2	19.9	25.33	32	23	.....	6.37	7.80	7,220	4,980	12.43	4.2	C. T.	
	3	15.2	24.78	33	20	60	6.84	8.04	7,160	5,290	12.71	3.1	C. T.	Do.
	4	16.5	26.75	34	23	60	6.61	7.64	9,310	5,050	14.09	4.1	C. T.	
	5	15.4	27.68	33	26	67	7.48	8.36	7,210	5,130	16.80	2.7	T.	Do.
Average	.....	16.8	26.60	32	22	61	6.99	8.04	7,748	5,018	14.05	3.8		
10-inch butt	6	14.6	25.80	27	28	71	7.08	9.55	9,060	5,940	18.75	4.0	C. T.	Wide checks.
	7	18.3	23.68	24	20	42	8.28	9.71	6,810	4,860	11.97	3.0	T.	At ax cut, badly checked.
	8	17.6	24.87	27	26	.....	8.08	9.55	7,260	5,310	14.38	3.8	C. T.	
	9	18.1	27.98	23	28	64	8.42	10.03	7,130	4,780	10.31	3.3	C. T.	Grain slightly spiral.
	10	16.9	23.18	24	19	57	8.59	10.03	4,480	3,190	11.27	1.5	T.	Grain spiral.
Average	.....	17.1	25.10	25	24	59	8.09	9.77	6,948	4,816	13.33	3.1		
12-inch butt	11	21.8	23.65	23	20	55	9.71	11.30	5,310	3,530	9.05	2.7	C. T.	Grain spiral, 4 knots in plane of failure.
	12	19.9	22.02	23	25	49	9.55	11.77	3,745	2,875	6.85	1.2	T.	Grain spiral.
	13	17.9	19.77	23	17	62	9.31	10.82	5,860	4,550	11.16	2.1	T.	
	14	19.1	25.55	22	22	61	9.95	11.14	6,350	4,340	11.62	3.0	T.	
	15	17.7	25.42	21	21	53	9.71	11.81	6,230	4,220	10.75	2.5	T.	Crooked and unusually knotty.
Average	.....	19.3	23.28	22	22	56	9.73	11.51	5,409	3,741	9.57	2.3		
Lodgepole pine (fire killed) cut from timber after standing dead for 30 years:														
8-inch butt	1	11.5	25.00	45	15	22	6.68	7.48	3,843	3,195	9.64	1.4	T.	Grain slightly spiral.
	2	14.5	26.49	45	18	13	7.16	8.12	7,780	5,390	11.43	5.6	C. T.	Do.
	3	12.9	25.96	39	15	36	7.08	8.59	6,390	3,850	10.95	2.4	C. T.	Do.
	4	14.6	24.66	34	17	12	7.16	8.91	5,310	4,910	9.58	1.7	T.	Do.
	5	12.4	24.93	37	12	30	6.45	8.59	4,190	3,880	9.98	.8	T.	Do.
	6	13.3	25.48	51	17	42	6.53	7.88	5,850	4,660	11.83	2.2	T.	Do.
	7	13.4	25.80	36	17	20	7.16	8.59	6,940	6,720	12.51	2.3	T.	Grain slightly spiral, crooked.
	8	12.8	27.17	36	17	14	7.64	8.59	5,995	4,020	12.23	1.8	T.	Grain spiral.
	9	11.7	25.49	34	20	.....	6.92	8.75	4,330	4,190	10.17	1.0	T.	Do.
Average	.....	13.7	25.66	40	16	24	6.98	8.39	5,625	4,649	10.92	2.1		

[1] C indicates compression failure; T, tension failure.

TABLE 16.—*Data on individual bending tests of air-seasoned round beams (16 feet long; span, 15 feet; third-point loading)*—Continued.

Species and size.	Ref. No.	Moisture.	Approximate dry weight (volume as tested).	Rings per inch.	Summerwood.	Sapwood.	Diameter.		Modulus of rupture.	Fiber stress at elastic limit.	Stiffness factor $\left(\frac{P}{Id}\right)$	Work to maximum load.	Manner of failure.[1]	Remarks.
							Top.	Butt.						
Lodge-pole pine (fire killed) cut from timber after standing dead for 30 years—Con.		*Per cent.*	*Lbs. per cu. ft.*		*Per cent.*	*Per cent.*	*Inches.*	*Inches.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*		*Inch lbs. per cu. in.*		
10-inch butt	10	14.4	26.36	42	20	36	8.20	9.31	7,350	5,570	10.85	3.4	C. T.	Grain spiral.
	11	13.3	27.23	39	17	19	7.64	10.03	6,840	4,060	8.06	3.4	T.	Do.
	12	12.7	24.62	24	15	26	7.88	10.35	8,970	6,400	13.26	4.2	T.	Unusually knotty.
	13	12.4	21.43	40	11	25	8.75	10.43	2,690	2,585	9.77	.5	T.	Grain spiral.
	14	12.1	25.00	36	14	21	7.64	10.03	3,165	2,870	9.35	.8	T.	Grain spiral, crooked, unusually knotty.
	15	12.6	24.67	26	13	33	8.91	10.51	4,820	4,660	10.53	1.5	T.	Grain slightly spiral.
	16	12.4	27.03	32	14	21	8.28	10.66	6,350	5,280	9.28	2.8	T.	Grain slightly spiral, unusually knotty.
	17	12.6	.....	26	14	17	8.67	9.87	5,650	3,800	11.46	1.6	T.	
	18	13.4	27.63	35	14	19	8.28	10.03	6,610	5,030	9.33	3.4	T.	Grain spiral.
	19	13.2	23.58	42	17	22	8.44	9.87	5,210	4,630	13.53	1.4	T.	Grain slightly spiral.
Average	.....	12.9	25.28	34	15	24	8.27	10.11	5,166	4,489	10.54	2.3		
12-inch butt	20	12.4	28.20	29	19	15	9.15	11.46	7,310	5,960	12.29	3.8	T.	
	21	13.4	25.03	24	15	36	9.55	12.09	2,060	1,343	8.12	.4	T.	Grain spiral, apparently rotten, badly checked.
	22	12.1	24.39	31	14	24	9.23	12.17	3,452	3,235	8.17	.7	T.	Apparently rotten and unusually knotty.
	23	13.0	28.46	32	16	31	9.07	12.33	5,070	4,350	8.79	1.8	T.	Grain spiral, unusually knotty.
	24	15.3	26.26	29	17	31	10.98	12.49	5,700	3,810	9.34	2.9	T.	Grain spiral.
	25	12.0	24.87	37	14	20	9.15	11.54	4,740	4,440	10.11	1.4	T.	Do.
	26	13.8	29.79	32	18	15	9.55	12.25	6,090	5,070	10.41	2.6	T.	Do.
	27	13.3	26.43	30	13	14	10.19	12.41	4,880	4,480	11.33	1.6	T.	Do.
	28	15.3	26.15	29	16	13	11.14	12.49	3,445	3,155	9.73	.9	T.	Do.
	29	14.6	24.53	37	8	21	9.95	12.30	4,410	3,665	10.33	1.4	T.	Grain spiral, knotty, and crooked.
	30	16.6	27.03	31	13	16	9.39	12.09	4,760	3,670	9.63	1.6	T.	
Average	.....	13.8	26.46	31	15	22	9.16	12.15	4,720	3,925	9.84	1.7		

[1] C indicates compression failure; T, tension failure.

MANNER OF FAILURE.

The prop failures were quite uniform. Compression wrinkles occurred usually through one or more knots and, if the prop had a slight bend in it, the wrinkles were on the concave side at the point of greatest eccentricity. If this bend were at all prominent, tension often occurred and in several instances the prop separated in two parts as in the brittle cap failure. The influence of checks on the form of failures was quite noticeable in the dry props, the shortening of the props giving the check, if spiral, the appearance of "unwinding" as in the strands of a rope. Figure 6 shows this effect to some extent.

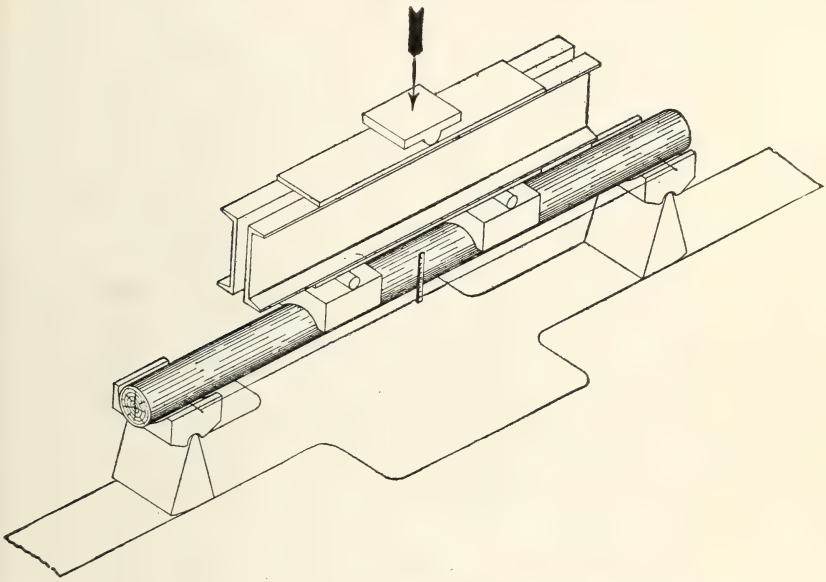


FIG. 7.—Method used in testing mine caps in bending.

CAPS.

The failures of the green caps were quite uniform in character among the various species. Near or at the maximum load, compression took place on the upper surface between the loading points. The load fell off slowly, and if continued, failure by tension ultimately took place. The green Alpine fir caps, however, had a larger proportion of tension than compression failures, and the Douglas fir had approximately the same number of each.

The dry caps, as far as could be detected by the eye, generally failed in tension near the center. Occasionally compression wrinkles occurred, but the failures were more often sudden, and some indicated brittle material. There was no material difference in the failure of the different species. In the dry material the tension splinters often ended at a check, but it was not apparent that the type of failure or

strength of the specimen was definitely influenced by the seasoning cracks, even when more or less spiral.

BEAMS.

The beam failures were similar to those occurring in the caps. The water-soaked material failed almost entirely in compression on the upper surface, the failure wrinkles becoming visible shortly before the maximum load was reached. Some of the green beams had a very large deflection, and the stress-strain curves were typically somewhat flat topped. The dry beams failed in tension, sometimes accompanied by failure in compression.

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